Essays in Macroeconomics using Microdata

by

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Declarations

This thesis is submitted to the University of Warwick in support of my application for the degree of Doctor of Philosophy. It has been composed by myself and has not been submitted in any previous application for any degree.

Chapter two is a collaboration with Huw Dixon. It started during my stay as a visiting scholar at Cardiff Business School in spring 2016.

Abstract

Price and wage setting are key elements in empirical and theoretical macroeconomic research. In recent years, large micro datasets with millions of observations have expanded our knowledge of wage and price setting practices. Aside from addressing old questions, new salient facts have emerged and have led to improvements, clarifications, criticisms and even new research lines.

One of these new findings in microeconomic research is the high degree of heterogeneity in the behaviour of price and wage setters. This dissertation adds to the research of using large micro datasets to document heterogeneity in price and wage setting, its implications for aggregate dynamics and potential drivers shaping heterogeneous responses.

In chapter one, we provide an introduction to our research on price and wage heterogeneity and provide a short summary of the following two chapters.

In chapter two, we merge three large price and wage micro-datasets at industry level and show that the frequency of price and wage adjustments are positively correlated. Furthermore, using a multi-sector DSGE model, we find that adding heterogeneity in both prices and wages generates small differences in aggregate dynamics compared to a model with heterogeneity in only one of them.

In chapter three, we investigate whether price responses to exchange rate shocks, the so-called exchange-rate pass-through, are asymmetric across regions and type of goods. Results suggest heterogeneous pass-through elasticities and that regional and industry characteristics play a role in shaping this heterogeneity. For instance, distance to the border, import intensity, price change dispersion and expenditure share affect positively the degree of pass-through; while regional market density has a negative relationship with pass-through rates.

In chapter four, we conclude by presenting a recap of findings from the two main chapters of this dissertation and outline future research.

Chapter 1

Introduction

Price and wage setting are key elements in empirical and theoretical macroeconomic research. In recent years, large micro datasets with millions of observations have expanded our knowledge of wage and price setting practices. Aside from addressing old questions, new salient facts have emerged and have led to improvements, clarifications, variations, criticisms and even new research lines.

One of these new findings in microeconomic research is the high degree of heterogeneity in the behaviour of price and wage setters (e.g. Bils and Klenow [2004], Nakamura and Steinsson [2008]). In spite the great deal of heterogeneity in wage and price setting found in large-scale surveys, most studies keep employing simplified frameworks at odds with this heterogeneity (see Smets and Wouters [2003], Gali and Monacelli [2005]). Also, it is not clear what are the drivers of these asymmetric price and wage responses to aggregate shocks (Campa and Goldberg [2005], Le Bihan et al. [2012]).

This dissertation adds to the research of using large micro datasets to document heterogeneity in price and wage setting, its implications for aggregate dynamics and potential drivers shaping heterogeneous responses.

In chapter two, "Price- and Wage-setting Heterogeneity and Implications in a New Keynesian Economy", we bring together two strands in the nominal rigidities literature that have been treated independently so far. On the one hand, studies using microdata analysing price adjustments, such as Bils and Klenow [2004]; Nakamura and Steinsson [2008]; Klenow et al. [2010]; Dixon and Kara [2010]. On the other hand, there is a growing body of literature that focuses on wage setting. See for instance, Barattieri et al. [2014]; Messina and Sanz-de Galdeano [2014]; Le Bihan et al. [2012].

To that end, three large price and wage micro-datasets are merged at industry level. To the author's knowledge, this is the first study merging price and wage data at such large scale.

Thus, in chapter two we investigate if the frequency of price and wage changes, commonly assumed independent one from each other in macro literature, display similar dynamics. Thus, studying jointly prices and wages new stylised facts emerge from the data: (i) the frequency of price adjustment is positively correlated with the frequency of wage updates across industries; (ii) wage stickiness is greater than the stickiness of reference prices but lower than posted price rigidities; (iii) frequency of adjustments is heterogeneous across industries for both prices and wages; (iv) absolute size of price adjustments is heterogeneous for prices but less clear for wages; and (v) frequency and size of adjustments are negatively correlated, not only for prices but for wages as well.

As it has been argued in previous studies, heterogeneous nominal rigidities might have major implications for aggregate dynamics. To that end, a multi-sector DSGE model is used to analyse what are the consequences of the empirical findings above mentioned. Using a time-dependent price and wage setting workhouse framework, results suggest that introducing simultaneously heterogeneous price stickiness and heterogeneous wage stickiness produces small differences in aggregate dynamics compared to a model where only one, either prices or wages, is heterogeneous while the remaining one is homogeneous in their degree of stickiness. Hence, further complicating the model to encompass both sources of heterogeneity at the same time has little payoff in terms of real effects and persistency. Though, any heterogeneous economy generates far more real effects than any homogeneous economy. Therefore, New Keynesian models abstracting price or wage heterogeneity neglect an important channel of monetary policy effects.

As a bypass, and since adding heterogeneous nominal rigidities obscures an already complicated model, we revisit the question of what calibration a homogeneous economy should follow in order to generate the same real effects as a heterogeneous economy. Our analysis suggests that a homogeneous economy calibrated with 3/4 of the weighted mean of frequency of price and wage adjustments generates the same real effects as the heterogeneous economy.

By looking at the clear overlap between price and wage rigidities, chapter two represents an important contribution in the nominal rigidities literature. Despite large and growing number of studies using microdata to analyse nominal rigidities, very little is known about the relationship and implications of the heterogeneous frequency of price and wage adjustments. Scarce wage microdata or perhaps the inability to merge price and wage data at firm/industry level remain important hurdles for researchers. Perhaps the early work by Druant et al. [2012] and Bertola et al. [2012] from the Wage Dynamics Network (WDN) represent the first ones to highlight the presence of a relationship between the frequency of price and wage adjustments.

Hence, the above findings call for more work to reconcile price- and wage-setting practices observed at micro level and aggregate dynamics from macro models. Indeed, price setting heterogeneity has being gaining space in New Keynesian literature. Research by Carvalho [2006]; Dixon and Kara [2010]; Kara [2015] stress the importance of taking micro evidence seriously in DSGE modelling. Frameworks incorporating price heterogeneity fit better the data and avoid ad-hoc solutions found in "representative-agent" models. However, these models abstract from wage heterogeneity. Therefore this chapter fills in this gap in the literature.

The second chapter examines price and wage rigidities in the context of a close economy. That is, the role of external factors, such as the exchange rate, in domestic prices and wages is left out in this setup. In the chapter that follows, I move into an open economy setting and, under the fresh lens of microdata, revisit one of the most important topics in international macroeconomics, the so-called Exchange Rate Pass-Through.

In chapter three, "Heterogeneous Exchange Rate Pass-Through: Micro-Level Evidence From Mexico", the attention is centred at examining the questions: are price responses across regions and type of goods asymmetric to exchange rate shocks? if so, what are the likely factors determining these responses?

The relation between prices and exchange rates is one of the classic topics analysed in international macroeconomics. Though, much of the previous research in this area focuses on the response of headline CPI to exchange rate fluctuations (e.g. Taylor [2000]; Goldberg and Campa [2010]). These studies imply that the pass-through of exchange rates to prices is homogeneous for across the economy. Another strand in the literature focuses on whether pass-through is endogenous to the domestic economy i.e. what drives the degree of pass-through (e.g. Campa and Goldberg [2005]; Fue [2012]).

Chapter three fits right in the heart of these areas of research. Building on the idea by Goldberg and Campa [2010] that pass-through is different across countries, we use the Mexican economy as a case study to analyse whether pass-through is heterogeneous within the country. Also, this research contributes to existing knowledge of industry- or regional-specific characteristics determining the degree of pass-through, as exposed in early work by Burstein et al. [2003]; Berger et al. [2012]; Corsetti et al. [2005]; Dev [2010].

Estimates suggest that pass-through is incomplete at most horizons, industries and regions. Moreover, great deal of heterogeneity is found in pass-through elasticities. For instance, in the short run, some regions exhibit up to four times larger pass-through rates than other urban areas. These asymmetries are persistent also at longer horizons. Furthermore, pass-through pace is heterogeneous as well. In other words, in some regions exchange rate effects take less than a year, whereas some other regions take nearly two years. In addition, previous findings arguing that pass-through is heterogeneous across industries is confirmed. On average, for instance, tradable good categories display higher pass-through elasticities than services.

In contrast to most pass-through studies estimating price elasticities only, this research takes a step further and assess local and industry characteristics driving the pass-through responses. We study factors such as distance to the north border, market density, demand conditions, economic development, import intensity, price change dispersion and expenditure share. We find that affecting positively pass-through elasticities are distance to the border, import intensity, price change dispersion and expenditure share. In contrast, market density has a negative relationship with pass-through rates. Moreover, we find that demand conditions and economic development are positively associated with tradable goods' pass-through responses.

Hence, results from chapter three has a number of implications for exiting pass-through literature. First, we confirm that pass-through is incomplete but not as low as what aggregate data suggests, as argued by other microdata studies like Auer and Schoenle [2016]; Broda and Weinstein [2006]; Gopinath and Rigobon [2008]. Second, our findings welcome further studies regarding heterogeneous price responses to exchange rates. Richer and detailed datasets across locations in a relatively homogeneous economy are required in order to shed more light to our results. Third, future research should focus on exchange rate pass-through to the service sector. Chapter three suggests that some service prices go against the common belief that (due to their non-tradable component) they exhibit low pass-through.

Finally, chapter four concludes by summarising, discussing the implication of this research in the current literature and considering possible directions for future research.

Chapter 2

Price- and Wage-setting Heterogeneity and Implications in a New Keynesian Economy

2.1 Introduction

Nominal frictions are introduced in macroeconomic models for addressing real effects of monetary disturbances. Thus, measures of price and wage stickiness are embedded in New Keynesian models studying the effects of monetary policy. These measures are found to have determinant influence on the degree of monetary non-neutrality, inflation persistence and optimal monetary policy rule.

A standard assumption in New Keynesian models is that frequency of price and wage adjustments are set independently (and exogenously) one from the other, despite their obvious relationship through the cost function (marginal cost). Yet, little is known empirically about the joint relationship of price and wage rigidities.

We use monthly economy-wide microdata on consumer prices and wages, merged at industry level, to provide new evidence about the interaction of these two sources of nominal rigidities and its implications in a DSGE model. Our contribution to the empirical study of nominal rigidities is fivefold.

First, we provide evidence that the extensive margin of price adjustments is positively correlated with the extensive margin of wage changes across different industries. In other words, industries resetting more often prices also readjust wages more frequently. This result holds after controlling for industry-specific labor intensity and/or considering the informal labor market and/or accounting for potential endogeneity issues. We analyse the possibility that the intensive margins (absolute size) of price and wage (non-zero) changes are positively correlated at industry level. However, this relationship turns out to be not robust. Second, we document that reference prices (i.e. excluding transitory prices) are stickier than wages, and wages are stickier than posted prices. Third, frequency of adjustments is heterogeneous across industries for both prices and wages. Forth, absolute size of price adjustments is heterogeneous for prices but less clear for wages. And fifth, we confirm that, consistent with state-dependent pricing literature, the frequency and size of adjustments are negatively correlated, not only for prices, but for wages as well.

Then, using a time-dependent price- and wage-setting framework we analyse what are the implications of embedding our extensive margin results in a New Keynesian economy. In other words, this research use a multi-sector New-Keynesian economy where each sector (industry) sets prices and wages à-la-Calvo. The Calvo distribution (i.e. set of Calvo pairs- prices, wages) is calibrated from the empirical section summarised above.

We find that heterogeneous nominal rigidities have strong implications in aggregate dynamics of the model. For instance, any heterogeneous economy generates far more real effects than any homogeneous economy with the same mean. However, no significant differences were found when both prices and wages are heterogeneous relative to cases in which only one, either prices or wages, is heterogeneous and the remaining one is homogeneous. Also, since adding heterogeneous nominal rigidities obscures an already complicated model, our analysis suggests that a homogeneous economy calibrated with 3/4 of the weighted mean of frequency of price and wage adjustments generates the same real effects as the heterogeneous economy.

The joint study of wage and price stickiness is relevant in micro-founded New Keynesian DSGE models for numerous reasons.

For instance, macroeconomic models predict that aggregate price level inertia hinges on wage rigidity. As Basu and House [2016] explain surveying wage setting literature, price level responds sluggishly to marginal cost adjustments. As wages are the largest component of the marginal cost (by producing real value added), wage stickiness reinforces price stickiness. Hence, understanding the interactions of price and wage rigidities is essential for aggregate dynamics in macro models.

In addition, the reaction of prices and wages to shocks depends on several factors: (i) the adjustment mechanism generating nominal rigidity (e.g. type of contracts ruling prices and wages behaviour), (ii) the length of the contracts (i.e. the parameters chosen to calibrate the duration of prices and wages) and (iii) the degree of staggering or synchronisation of price and wage adjustments.

Moreover, real wage rigidity in DSGE models stemming from the interaction of nominal wage and price stickiness generates a higher persistence of inflation. For instance, if real rigidity is mechanically induced by wage indexation to past inflation, the trade-off between output and inflation stabilisation faced by the monetary authority is worse.

Despite the pivotal role of nominal rigidities in macro modelling, there is no unambiguous evidence on which adjustment rule better characterise price- and wage-setting. The most common assumption in macro literature is that the frequency of price adjustments and the frequency of wage changes are equal (e.g. Erceg et al. [2000]; Galí [2015]). Our purpose in this chapter is to shed light on the interaction of price and wage rigidities and the implications of using a realistic heterogeneous Calvo calibration in an otherwise standard DSGE model.

The analysis begins from two large microdata sets providing monthly price and wage observations across a wide range of industries in Mexico. The first dataset is compiled by the Bank of Mexico (Banco de Mexico) and report price dynamics observed at the retail level. Furthermore, we use administrative wage data provided by the Mexican Institute of Social Security (IMSS). Since our administrative wage data neglects the informal labor market, we complement our analysis by using microdata from self-reported earnings data including formal and informal workers. The later survey is gathered by the National Institute of Geography and Statistics (INEGI). Price, wage and earnings data are merged using the North American Industry Classification System (NAICS) and IMSS's industry classification. Our paper exploits the industrial partition in these datasets to study price and wage frequency and size of adjustments.

This chapter is organised as follows, section 2.2 summarises literature related to heterogeneous price and wage rigidities. Section 2.3 describes the micro datasets. Section 2.4 studies the frequency of adjustments. Section 2.5 analyses the absolute size of adjustments. Section 2.6 assess the interaction between frequency and size changes. Section 2.7 shows the complete distribution of price and wage (non-zero) changes. Section 2.8 characterises and summaries aggregate dynamics found in our DSGE model. Lastly, section 2.9 concludes.

2.2 Literature

In this section we first give an extensive review of empirical evidence on price and wage stickiness. We then summarise theoretical work analysing implications of heterogeneous price and wage rigidities for monetary policy. We finish this section by outlining studies using Mexico as a case study in the context of our research.

Price and wage rigidities have a direct effect of the real effects of monetary policy in DSGE models. Over the last fifteen years, there has been a growing number of empirical studies focusing on agents' (goods or labor) pricing practices as richer datasets become more available.

Regarding price stickiness, microdata from price indices, namely CPI and PPI, have emerged as an important data source as first studied by Bils and Klenow [2004]. In a similar fashion, and importantly for this research, analysis by Nakamura and Steinsson [2008] for the US; Álvarez et al. [2006] summarising studies from Euro-area economies; and Bunn and Ellis [2012] and Dixon and Tian [2017] for the UK exploit price indices' microdata. A clear pattern arises from these studies: prices of some product categories change more frequently than others. This heterogeneous pricing behaviour is confirmed in our CPI micro-dataset for the Mexican economy.

Microeconomic evidence on wage stickiness has been also an object of research since Taylor. In recent years there has been a renewed interest on studying wage stickiness using higher than annual frequency observations. This research, closely related to studies by Le Bihan et al. [2012] for France, Barattieri et al. [2014] for the US and Sigurdsson and Sigurdardottir [2016] for Iceland, focuses on how rigid nominal wages are. In contrast to the consensus on the price literature, the frequency of wage changes does not display much heterogeneity across industries according to these three studies. Interestingly, our study suggests more pervasive heterogeneity in the frequency of wage adjustments across industries. One potential reason for the starling difference with previous studies using similar datasets is that we use a more disaggregated industry classification. Le Bihan et al. [2012], Barattieri et al. [2014] and Sigurdsson and Sigurdardottir [2016] employ three, eight and five sectors respectively, potentially averaging out any heterogeneous behaviour. This dissertation uses 74 industries. Another potential reason could be associated to institutional frameworks. Previous studies have centred at advanced economies, whereas we analyse wage stickiness in an emerging economy.

All in all, heterogeneity in nominal stickiness is a clear pattern of microdata. However, macroeconomic models usually assume identical firms or workers, resetting goods and labor prices at the same (average) frequency of adjustment. Hence, a new generation of DSGE models have been developed to encompass and study the implications of different degrees of price and wage stickiness in the economy.

In order to account explicitly for heterogeneity in price and wage stickiness, macroeconomic literature has adopted the price-setting framework proposed by Calvo [1983].[1] That is, the economy is divided into a number of sectors and

[1]Important exceptions using different price-setting models accounting for heterogeneity are

each firm (union) changes its price (wage) with a sector-specific frequency of adjustment.[2,3]

Nonetheless, heterogeneity in wages using Calvo-style rigidities in DSGE models remains scarce. Little heterogeneity observed in the microdata (summarised above for France, US and Iceland) partially explains this gap in the literature. However, this chapter finds asymmetries on the frequency of wage changes across industries in Mexico. Therefore, our DSGE strategy is the first to critically assess the role of heterogeneous wage stickiness on aggregate dynamics. In fact, Kara [2015] suggests that heterogeneous wage stickiness may help to address the large variance of wage mark-up shocks in macroeconomic models as noted by Chari et al. [2009].

Moreover, heterogeneity in price- and wage-setting has been suggested to alleviate New Keynesian models' shortcomings in failing to reproduce inflation responses found in empirical VARs. See for instance Dixon and Kara [2010] and Kara and Park [2017]. Nontheless, macroeconomic literature has adopted habit formation and (price and/or wage) indexation, among other mechanisms, in search of reconciling New Keynesian models and empirical VARs. However, some of these mechanisms are at odds with microdata evidence. In line with Dixon and Kara [2010] and Kara and Park [2017], this chapter advocates that heterogeneity in price- and wage-setting can alleviate shortcomings in terms of the impact and persistence of inflation response to monetary policy shocks, while keeping the model consistent with micro evidence.

2.2.1 Mexico as a case study

The Mexican economy provides favourable ingredients for analysing price and wage dynamics. Mexico adopted a floating exchange rate after the so-called *Tequila crisis* in 1994, and from 1999 the Bank of Mexico began a gradual transition to an inflation targeting regime. Officially announced in 2001, the medium-term inflation target was set at 3.0% with a 1.0 percentage point variability range. Our analysis starts right after this implementation period by utilising data from 2002.

Likewise, since the adoption of the inflation targeting regime, the Bank of Mexico started to move towards a policy influencing the level of interest rates. From 1999 to 2007, the central bank established borrowed reserves as its key instrument.

Dixon and Kara [2011, 2010] with Taylor-type contracts and Nakamura and Steinsson [2010] using a menu-cost framework.

[2] Another Calvo-style setup reflecting the underlying heterogeneity observed in microdata is the Generalised Calvo economy. See Dixon and Le Bihan [2012] and Dixon and Tian [2017] for more.

[3] For a recent survey on multi-sector models see Taylor [2016].

Then, from 2008 the Bank of Mexico adopted as its policy instrument the overnight interbank interest rate (tasa de fondeo bancario). Thus, Banxico maintained the interest rate between 7.00% and 8.25% in 2008. In the light of the global financial crisis, Banco de Mexico cut the target rate by 3.75 basis points, from 8.25% to 4.50%, in the first half of 2009, where it remained until March 2013.

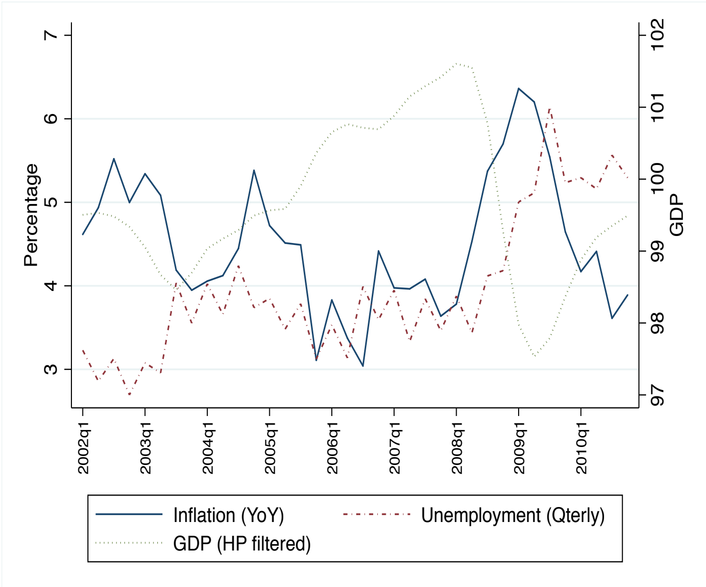
Figure 2.1 illustrates key macroeconomic variables in Mexico at time our research centres in. Though, our analysis builds in the use rich micro datasets (and not in aggregate indexes) to add on the study of nominal rigidities.

The study of nominal rigidities using Mexican microdata is not new in the literature. Gagnon [2009] use Mexican price microdata and compare frequency and size of adjustments in episodes of high and low inflation. On the one hand, his findings suggest that the frequency of price changes comoves weakly with inflation when the annual rate of inflation is low (below 15%). On the other hand, the average magnitude of price changes correlates strongly with the inflation rate. Although, this study is not directly comparable to ours since it uses data before 2002, his findings support the a-la-Calvo pricing mechanism used in this paper for the Mexican economy.

Furthermore, Gagnon et al. [2013] analyse price adjustments that are determined ahead of shocks and those that are either triggered or cancelled by shocks. Using VAT hikes from 1995 and 2010, Gagnon et al. [2013] calculate counterfactuals for the distribution of price changes and find that a large number of price adjustments were determined ahead of the tax hike. That is, Gagnon et al. [2013] observe a higher number of price changes around these dates, relative to times with no VAT shock. Hence, their findings speak against of a purely time-dependent pricing model.

Wage dynamics in the Mexican economy have been also studied before, mainly due to the trade liberalisation and migration between Mexico and the US. Relevant to our analysis, Castellanos et al. [2004] use administrative wage microdata from 1985 to 2001. Among their results, the authors document that a large fraction wage adjustments are equal to annual minimum wage increase. That is, wage changes of those earning above the minimum wage are also indexed to the minimum wage. Furthermore, they find only limited and decreasing downward wage rigidity in Mexico. With our data, we are able to update these results and find that most wage increases are between the minimum wage increase and the inflation goal set by the central bank.

Figure 2.1: Inflation, unemployment and GDP in Mexico



2.3 Data

We merge three large microdata sets. The first is CPI microdata gathered by the Bank of Mexico (Banco de Mexico). This is a confidential dataset containing product-level price dynamics used for CPI calculations. The CPI micro dataset has been used by Gagnon [2009] Gagnon et al. [2013] and Elberg [2016] in somewhat similar studies. The second data source are administrative wage records from affiliated workers to the Mexican Institute of Social Security (IMSS). Castellanos et al. [2004] use a similar dataset with quarterly observations, whilst our analysis utilises monthly observations. The third microdata set comes from the Mexican National Occupation and Employment Survey (ENOE) conducted by the National Institute of Statistics and Geography (INEGI). This is self-reported survey on earnings and other labor market characteristics from workers in both formal and informal sectors. This survey has been used extensively in the past. For instance Cano-Urbina [2015], Bargain and Kwenda [2011], among others.

A number of remarks are important to make before we describe our data. First, we refer as “wages” to statistics or findings drawn from the administrative (IMSS) dataset, and as “earnings” to figures calculated from the self-reported earnings (INEGI) survey. Second, we primarily centre our attention in comparing price and wage data since wage and earnings data exhibit similar patters. Third, wage and earnings datasets encompass industries across the whole economy. In contrast, our price data includes industries covered in the CPI only. Hence, we focus on industries in which we observe prices and wages/earnings, 74 in total.

For all aggregate statistics about the frequency and size of price/wage/earnings adjustments, we compute weighted figures across sectors unless we indicate otherwise. We use Bank of Mexico's CPI expenditure weights for this purpose.[4] Sectoral level statistics are unweighted averages within the sector.

Data on prices and self-reported earnings are merged according to the North American Industry Classification System (NAICS). Wage data is merged with the former two using IMSS's industry classification system, which has broad similarities with the NAICS. In what follows, the terms industry and sector are used indistinguishably. Data sets are described in further detail bellow.

Before we describe each of our datasets in great detail, we believe it is important to highlight how our price stickiness and wage rigidities comparison differs relative to previous work.

As summarised in the previous section, most studies analyse price-setting independently from wage-setting. Thus, these studies cannot relate whether price stickiness hinges on wage stickiness.[5] Exceptions are research by Druant et al. [2012] and Bertola et al. [2012] from the Wage Dynamics Network (WDN) and Carlsson and Skans [2012].

We differ from these papers in various directions. Druant et al. [2012] and Bertola et al. [2012] base their research on qualitative data (interviewing firms' managers about their price-setting practices), whereas our analysis employs quantitative data from actual price and wage quotas. Moreover, Carlsson and Skans [2012] use producer prices on annual basis. In contrast, this research uses monthly data, which is more convenient when measuring adjustment rates. Although Carlsson and Skans [2012] utilise firm (plant) level data, his analysis only comprehends manufacturing industries, while our analysis is through homogeneous goods and services industries.

To our knowledge, this is the first paper merging sectoral microdata on prices and wages at such scale. The industry coverage allows addressing the heterogeneity commonly found in previous research on nominal rigidities (Nakamura and Steinsson [2008]; Le Bihan et al. [2012]), and the monthly frequency of observations permits a novel comparison between these two sources of nominal stickiness. Most importantly, studies on wage rigidities are typically available at annual and rarely at quarterly frequency, whereas our analysis studies monthly frequency of adjustments.

[4]Using the industries shares of GDP had only limited impact in our results.

[5]As Basu and House [2016] argue, wage rigidities might reinforce price stickiness since the largest share of the marginal cost of producing real value added are labor costs.

2.3.1 Price data: CPI microdata

We use monthly price dynamics of individual goods and services observed from June 2002 to December 2010. The number of monthly observations ranges roughly from 53,000 in 2002 to 81,000 in 2010 due to sample extensions throughout the observation period. The CPI dataset classifies priced items into product-categories (equivalent to BLS's ELIs in the US or ONS's COICOP classes in the UK), which can be grouped into 4-digits NAICS industries.

We drop product categories whose prices are regulated (e.g. gasoline, electricity, etc) or reported as an index due to its particular treatment by the Bank of Mexico (e.g. landline fee, car insurance, etc). Fresh food is excluded as well due to its stochastic component (e.g. subject to weather conditions or time-varying quality affecting prices). We also neglect from the analysis the top and bottom 0.5% of monthly price variations per sector as treatment for outliers. All in all, our price data represents 72% of Mexico's CPI.[6]

Prices are inclusive of sales as long as these sales are conditional on purchasing a single item (e.g. 3x2 offers are not included). Also, seasonal clearance sales are not included. In the following section we describe extensively our strategy with respect to sales treatment.

With respect to an item being out of stock, the last effectively observed price is carried forward. This is the original sampling methodology and our dataset does not flag out stockouts. This procedure is not unusual in the literature (for instance, see Kle and Gopinath and Rigobon [2008]). As noted by Nakamura and Steinsson [2008], this approach would be appropriate if one assumes regular prices are systematically readjusted at the end of stockouts. Furthermore, if an item is replaced by another product, our data reports no price variation. Although this might downward bias our estimates of frequency of changes, product rotation is believed to be around 1% per month.

2.3.2 Wage data: Administrative data

We use administrative records from the Mexican Institute of Social Security (IMSS) from January 2003 to December 2010. These administrative records constitute a census of all formal workers employed in the private sector. It excludes a fraction of the labor force, namely government employees (affiliated to a different social security system) and those employed by the informal sector (not affiliated to any social security system).

[6]Original dataset contains 100% of consumer expenditures.

Our data is a panel of employee clusters observed on a monthly basis. Clusters are defined by state, district, county, firm's size, age, gender, industry and income level. We observe the wage bill and number of workers within the cluster.[7] The original dataset contains on average around 3 million clusters every month. It is worth mentioning that, given the granular characteristics defining each cluster, nearly 80% of clusters have only one or two workers. Hence, a vast majority of clusters actually contains individual wages.

We then define the (log) wage per worker as the ratio of wage bill and the number of workers in that cluster. We only compare monthly wages if and only if the cluster's size has not changed. This is in order to avoid including false-positive wage adjustments due different number of workers in the cluster. If the size of the cluster varies, we consider it as missing value. Also, since we compare constant size clusters from one month to another, we assume workers in the cluster are the same workers in consecutive months.

We analyse clusters from workers classified as permanent workers only. They represent nearly 93% in our sample. We leave out from the analysis temporal workers as most of these positions are seasonal and/or upon the completion of a specific task.

After these specifications, our final dataset contains roughly 2 million clusters per month representing more than 5.4 million workers.

Before moving on to the next data source, there are a number of important issues to highlight regarding IMSS's administrative records.

First, we do not weight clusters by number of employees. One of the motives is that we cannot observe if all workers in the cluster have indeed experienced a wage adjustment. Additionally, identification of wages changes in big size clusters is more difficult due to the month-to-month same-size constraint. As estimates are based on millions of clusters, most of them of relative small size, we opt to compute unweighted statistics within sectors.

Second, workers should not receive less than one minimum wage by law. This legislation affects the frequency of wage changes for those earning between the old and new minimum wage. Moreover, the base salary reported to the IMSS is capped at 25 minimum wages. This celling also affects the frequency of wage adjustments as every time there is minimum wage update, the reported wage celling is also readjusted, when in fact the worker might not have experienced any wage change. Hence, we carry our analysis excluding workers earning exactly one (4.3%)

[7] Wages in IMSS data are reported in a standardised measure, called base salary. The base salary is a comprehensive measure of salary plus benefits reported as a daily wage, regardless if the employees are paid on a weekly or monthly basis. The monthly wage bill in our dataset is calculated from the last base salary of the month as reported by IMSS.

or 25 (1.8%) minimum wages.

Third, recent studies base their wage stickiness measures from administrative wage records as reported by employers. Although misreporting and rounding effects may still be present, these types of measurement errors might be less of a concern compared to household survey datasets. As argue by Altonji and Devereux [2000], Gottschalk [2005] and Le Bihan et al. [2012], employers provide superior quality data because what they report have direct implications with the fiscal or pension authorities. In fact, Barattieri et al. [2014] stress that, in comparison with the US, other countries have access to administrative data from payroll or tax records, which reduces measurement errors significantly. This is precisely the case for our administrative wage records as reported by the Mexican pension authority IMSS.

We believe our dataset is unlikely to suffer from measurement errors due to rounding. On average, 89.5% of our wage observations include the cents paid. Regarding misreporting, it is in the worker's interest that employers accurately report her base wage since many of her benefits (e.g. pension, disability insurance, etc.) are proportional to the reported base wage. Although employers have incentives to underreport wages (lowering their social security quotas), the IMSS has the legal status similar to an autonomous fiscal authority. That is, it can engage in legal actions to collect quotas, including seizing firm's assets, which enhances its ability to enforce the law.

Nonetheless, our wage dataset has three main drawbacks for accurately measuring labor costs rigidities.

First, the monthly base wage reported by IMSS is calculated using the wage and time specified on the labor contract. It does not report overtime pay. If the employee works extra hours and those extra hours are paid at a different rate, failing to observe hours worked in our dataset would arguably downward bias our frequency estimates.

Second, our micro-cluster structure may rise to wage trajectories that may not necessarily correspond to the same worker across time. In other words, it could be the case that an employee is substituted by another worker with fairly similar demographics and base salary. Le Bihan et al. [2012] faces a similar issue and tries a number of specifications as robustness checks. However, in our context, if a new hired has a substantial different wage and/or have different demographics (e.g. age), he or she would fall into a different micro-cluster. As a result, these instances would produce missing observations. As Le Bihan et al. [2012] emphasise, to the extent that this measurement issue may be present, it would underestimate the rigidity of base wages.

Third, as base salaries are reported by employers, the IMSS dataset does not account for between-job wage changes. These cases also affect our frequency of wage changes if the employee falls into a different micro cluster, even if he or she is hired by another firm in the same industry. The use of household surveys (e.g. Barattieri et al. [2014]) or employees' tax records would allow to calculate between-job wage changes.

2.3.3 Earnings data: Self-reported survey

In order to extrapolate wage rigidities in both formal and informal sectors, we use microdata from the National Occupational and Employment Survey (ENOE). The ENOE is a rotating panel where households are surveyed five times on a quarterly basis. We consider the period from 2005 to 2010 due to methodology changes in the survey.

The ENOE offers job related characteristics (as well as demographics) about each family member in the household who is 15 years of age or above. We observe individual monthly gross earnings, hours worked, whether the family member is affiliated to any social security system (e.g. IMSS), as well as employer's information such as NAICS industry code, firm's size, etc.

The surveys' sample is probabilistic, hence, it provides expansion factors ensuring its representativeness relative to the overall and industry labor market. Thus, after deleting industries in which we do not have price data, our sample comprehends over 60,000 observations, representing nearly 16 million workers, every quarter.

We construct a measure of (log) hourly earnings per worker and we define an income change as the (log) difference of hourly earnings in consecutive quarters. It is worth mentioning that data from self-reported earnings might be subject to measurement errors in both variables of interest, earnings and hours worked. We revisit this issue and cleaning procedure in the next section.

2.4 Frequency of price and wage adjustments

In this section, we present statistics on the frequency of price and wage changes in the Mexican economy. We begin by making some precisions on the treatment of sales in the price data, as well as measurement error corrections in the self-reported earning data. Then, we describe aggregate statistics for our different data sources, proceed by an extensive comparison of price and wage adjustments across industries.

First, the literature on nominal rigidities has highlighted that transitory price changes may substantially bias measures of price stickiness.[8] Since our data lacks sales indicators, we present price statistics using posted prices, as well as reference prices defined as the 3-months modal price. The latter approach, similar toEichenbaum et al. [2011] work, is adopted as a sales filter. Our conclusions do not change if we use 6-months modal prices instead as reported in our Appendix.

Second, our motive for using self-reported earnings data is that it contains data from formal and informal workers. As opposed as our administrative data, containing formal workers only, it provides a complete picture of wage dynamics in Mexico's labor market. However, literature in labor economics has widely documented measurement errors on self-reported earnings data (e.g. Akee [2011]). In order to clean surveyed data from measurement errors we apply the following cleaning approach. We first estimate the frequency of price change in our administrative data reported by IMSS. Then, ENOE's questionnaires ask whether the worker is an IMSS affiliated or not. We separate these workers into a subsample, then fit an error band (per industry) in terms of earnings variation such that the frequency of earnings adjustments in this subsample matches the frequency of wage changes (observed in the administrative data). Finally, we impose the same error band to all workers, including those not IMSS affiliated, and we recalculate earnings' frequency of adjustment.[9]

After cleaning our earnings data, wage and earnings frequencies of adjustment across industries are depicted in figure 2.2. Remarkably, the positive slope in the graph can be interpreted as industries' stickiness (relative to other industries) do not change drastically if you consider (or not) both formal and informal workers. Also, since most industries lay below the identity line, it represents that informal workers reset wages slightly more often than employees in the formal sector. This result is likely to prevail if the menu-cost of reseting formal workers' wage is greater than those in the informal sector, which is likely.

Third, our price and wage datasets contain monthly observations, whereas

[8]For example, Kehoe and Midrigan [2007] and Nakamura and Steinsson [2008].

[9]Alternative methods have been proposed to alleviate measurement errors in the context of measuring wage stickiness. For instance, Akee [2011] compares self-reported earnings to administrative wage records; and Gottschalk [2005] and Barattieri et al. [2014] use time-series tests for breaks to discriminate between true and spurious wage changes. However, there are a number of limitations in our household survey dataset that prevent us to use any of the correction methods for measurement errors above mentioned. First, in the ENOE survey each household (and its family members) is interviewed five times. In contrast, Gottschalk [2005] and Barattieri et al. [2014] use 12 observations per worker to identify structural breaks in the individual wage time-series. Second, we are unable to match workers across ENOE and IMSS datasets for cross-checking the information as in Akee [2011].

our earnings data is quarterly reported. We use monthly statistics in both the empirical and theoretical part of this chapter. This is a novel feature of our wage data (most studies use annual data and only a handful utilise quarterly observations e.g. Le Bihan et al. [2012]). The expression for transforming self-reported earnings to monthly statistics is

$$\theta^i_{k,q} = \theta^i_{k,m} + \left(\theta^i_{k,m}(1-\theta^i_{k,m})\right) + \left(\theta^i_{k,m}(1-\theta^i_{k,m})^2\right)$$

where $\theta^i_{k,q}$ denotes quarterly and $\theta^i_{k,m}$ monthly frequency of adjustment in industry k for $i = [earnings]$. Needless to say, the expression above assumes that the probability of price adjustment is constant over time, regardless of when was the last price chance, consistent with the benchmark Calvo model.[10]

For completeness, we report the corresponding implied duration (in months). Assuming a constant hazard $\theta^i_{k,m}$, for $i = [price, wage, earnings]$, we define the corresponding implied duration as

$$d^i_{k,m} = -1/ln(1-\theta^i_{k,m})$$

Finally, aggregate statistics are weighted means/medians across sectors using the 2010 CPI's weights. All within sector statistics are unweighted statistics.

2.4.1 Aggregate frequency of adjustment

In this section, we summarise the weighted aggregates of the frequency of price, wage and earnings adjustments. We also present the implied durations, $d^i_{k,m}$, as defined above. These aggregate statistics are reported in Table 2.1.

Prices

The first and second row in table 2.1 report estimates for posted and reference prices. The median frequency of posted prices is 13.16%, whereas for reference prices it drops to 10.39%. The median implied duration is 7.09 and 9.12 months for posted and reference prices respectively. The mean is 19.94% for posted prices and 13.84% for reference prices. That is, around a 45% and 30% increase with respect to their medians respectively. This implies some skewness in the distribution of the frequency of price changes by sectors.

[10] Alternatively, we could have calculated the actual duration-dependent reset probabilities as in the Generalised Calvo (GC) model. In other words, using the hazard function as explained in Dixon [2010] and Dixon and Le Bihan [2012]. As in this dissertation we did not calculate duration of price and wage spells, we assume a constant hazard as in the baseline Calvo model.

Unfortunately there is no other study using the same dataset for cross-checking our estimates. The closest study is by Gagnon [2009] who uses data from 1994 until 2002 and reports an unweighted frequency of price adjustment of 43.4% including sale prices. It is not surprising that our estimates are below this figure as the *Tequila crisis* began in the eve of 1994.

Compared to studies from other developed economies, Mexico displays a similar degree of price stickiness. For instance, the median frequency of price changes is 19.3% including sales and 8.9% excluding sales in the US as reported by Nakamura and Steinsson [2008]. For the UK, Dixon and Tian [2017] exclude sales and substitutions and find a slightly higher statistic of 14%. Moreover, Dixon and Le Bihan [2012] study french data and calculate a weighted mean frequency of 19% including sales.

Wages and earnings

With respect of wages and earnings, aggregate statistics are summarised in the third and fourth row of table 2.1. As highlighted above, our surveyed data contains a sample of formal and informal workers, while the administrative dataset contains the universe of formal employees only with the advantage of less measurement errors.

The weighted median frequency of wage adjustments is 14.31%, whereas for self-reported earnings it is 18.81%. Implied duration is about 5 or 6 months depending the data used.

Using Mexican data, Castellanos et al. [2004] report that nearly 95% of wages change every year in 2000q4. Since the authors do not weight sectors and instead they use simple averages, our monthly frequency of adjustment is not strictly comparable to their figure.

Compared to the US or Europe, the Mexican labour market exhibits analogous wage stickiness to Europe. For instance, wage stickiness in France is about 14.7% as documented by Dixon and Le Bihan [2012]. In contrast, Barattieri et al. [2014] report higher wage rigidity in the US, around 9.9% wage changes per month.

2.4.2 Sectoral frequency of adjustment

In this section we describe the relationship between sectoral price, wage and earnings frequencies of adjustments. The complete set of industries and frequency of adjustments are listed in table 2.2.

Table 2.2 gives a good idea about the heterogeneous price and wage setting behaviour across different industries. The heterogeneous behaviour is not new in nominal rigidities research (e.g. Bils and Klenow [2004]). For instance, only 3% of *Parking vehicle services* fees vary every month on average, while around 45% of *Grains and seeds* related prices change in a month. Also, the effect of transitory prices varies dramatically by industries. A good example are the two measures of frequency of adjustments for *Fat and oil* goods: 48% when considering posted prices and only 19.64% when using reference prices. This effect is less prevalent in *Domestic personnel fees*, for instance, which exhibit 3.41% and 3.09% rates of change for posted and reference prices respectively.

Strikingly, the frequency of wage adjustments for most sectors is greater than the frequency of adjustments of reference price, but lower than posted prices.

We depict the industries' frequency of adjustments of posted prices and wages in figure 2.3a. A simple OLS regression gives a correlation of 0.586** between sectoral price and wage frequencies. The positive correlation holds after removing transitory prices by using reference prices. The correlation between the frequency of adjustments of reference prices and wages is 0.336*** as depicted in figure 2.3b. Looking at price rigidities on the vertical axis of figures 2.3a and 2.3b, the effect of transitory prices is clear.

The positive relationship prevails across our different metrics of frequency of adjustments. For instance, posted prices against earnings (figure 2.3c and correlation 0.539*), reference prices versus earnings (figure 2.3d and correlation 0.297*). Results using 6 months reference prices or wages without floors or caps are essentially the same and can be found in the Appendix.

To our knowledge this is the first paper documenting this positive relationship using both price and wage microdata. Druant et al. [2012] highlight similar findings based on qualitative questionnaire answers. In line with our results, the authors report that 73% of firms change wages and prices at a somewhat comparable frequency; and 40% of managers acknowledge the existence of some relationship between the time of repricing and wage updates.

In line with previous studies analysing nominal rigidities, we plot the distribution of implied duration across sectors in figure 2.4. These implied durations are calculated using the expression for $d^i_{k,m}$ as defined above and the frequencies of adjustment reported in table 2.2. Figure 2.4a and figure 2.4b confirm some of the results described above. Reference prices, which is our proxy for prices excluding sales, exhibit longer durations (i.e. fatter right tail) than posted prices. Similarly, implied durations from our wage data in figure 2.4c is centred around six or seven months; while figure 2.4d depicting self-reported earnings is centred at four or five months.

Endogeneity

Several studies have explored whether industries' heterogeneity in market and/or cost structure explains why price flexibility differs substantially across industries.

This chapter focuses on the latter, cost structure.[11] Previous work studying the correlation between input shares and the frequency of price adjustments have found an inverse relationship between the degree of labor intensity and price stickiness. See, for instance, Peneva [2011] with US consumer prices; and using producer price data Álvarez et al. [2010] for Spain, Dossche and Cornille [2006] for Belgium and Bertola et al. [2012] for Euro area economies. Results from these studies are only explained in case there is a causal relationship between wage and price stickiness. Intuitively, the idea of these studies is to link the volatility of labour price (weighted by its factor intensity) and the frequency of price changes. However, these studies are not able to show that relationship as they lack wage data.

Indeed, one of the main conclusions drawn from the IPN is indeed that wage persistence is an important factor behind price stickiness in the Euro area as summarised by Altissimo et al. [2006].[12] Similarly, Peneva [2011] argue that it is possible that a significant amount of wage rigidity, along with the heterogeneity in labor intensity, play an important role in the heterogeneity of price rigidities. Álvarez et al. [2010] state that given the low frequency of wage changes, we expect more labour intensive industries to carry out price revisions less frequently. Druant et al. [2012] use qualitative data from the WDN and establish that firms reset prices roughly at the same time as wage adjustments.

A novel contribution of this chapter is precisely to relate measures of price and wage stickiness across industries using quantitative data. Using better quality data, this chapter critically examines if wage rigidities generate price rigidities.

Following Álvarez et al. [2010] and Dossche and Cornille [2006], we regress the sectoral frequencies of price adjustments on sectoral frequencies of wage changes and additional determinants suggested by economic theory.

As the frequency of wage changes might be contemporaneously determined by the frequency of price adjustments, we cannot exclude that our regression suffer from an endogeneity problem, which leads to biased and inconsistent estimates. Hence, in order to control for this issue we rely on Instrumental Variable (IV) estimation.

[11] Carlton (1986) and Caucutt et al. (1999), Bils and Klenow (2004) and Klenow and Malin (2011) focus on market structure determining the degree of price flexibility.

[12] The relevance of understanding the relationship between wages and prices stickiness found from the IPN led to a follow-up research project named the Wage Dynamic Network (WDN).

We think of a linear model of the form

$$FPA_k = \beta\, FWA_k + \varepsilon_k$$

with the frequency of posted price adjustments in sector k (FPA_k) as dependent variable and the frequency of wage adjustments (FWA_k) as independent variable. In the presence of endogeneity bias, $E\,(FWA\,\varepsilon) \neq 0$, we need an instrument that is correlated with FWA, but not with FPA.[13]

We propose the share of minimum wage workers per industry as our instrument. The intuition behind our instrument is as follows. The minimum wage in Mexico changes only once a year.[14] Now, suppose all workers in a given industry earn exactly one minimum wage. In this hypothetical industry, all wages would be adjusted when the minimum wage changes. Since we use monthly data, this means that we would observe a wage change every twelve months. In other words, if 100% of workers earn the minimum wage, we would expect to have a frequency of adjustment equal to one twelfth. Similarly, as the share of minimum wage workers decreases per industry, the stochastic component of wage determination kicks in, presumably leading to more frequent wage adjustments. Although one might argue the opposite (that is, as the share of minimum wage workers decreases per industry, wage determination leads to less frequent than once a year wage adjustments), our wage statistics presented above suggest wages are reset, in general, slightly more frequently than once a year. Hence, we assume the fraction of workers getting the annual minimum wage increase in a given industry affects the frequency of wage changes in such industry, which in turn determines the frequency of price adjustments.

We calculate the share of workers earning up to 1.5 times the minimum wage, per industry, from our administrative data only. The main reasons to neglect informal workers come from the similarities with formal workers found and described in the previous section.

Table 2.3 reports results from our IV approach when treating posted prices as our dependent variable. The coefficient under the IV estimation in column 2 is nearly double the standard OLS regression in column 1, confirming endogeneity

[13]It is worth noticing that our approach is to focus on the effects of wages on prices, and not the opposite. The intuition is that goods' prices in a given industry rely heavily on wages (costs) in such industry. On the other hand, wages in certain industry depend on the aggregate price level across industries. Given the structure of our dataset, we centre our attention in the wage on price effects.

[14]This is the case at least during our observation period. More recently, there have been years (e.g. 2014 or 2015) with more than one minimum wage adjustment per year in Mexico.

issues. Diagnostic statistics, such as the F-statistic or the minimum eigenvalue, in column 2 discard concerns of weak instrumentation.

Given the limited number of industries in our sample, we can only take our analysis in few different directions. First, we consider an alternative instrument, namely the industry labor share. The intuition here is that as labour share becomes larger, unions or households have more bargaining power on wage adjustments, which in turn determines prices (only after affecting wages). The result of this approach is shown in column 3 of table 2.12 in the appendix. Although our coefficient of interest is positive and statistically significant (three times larger than the simple OLS), labour share turns out to be a weak instrument for FWA as shown from the F-statistic. Column 4 reports results from a 2SLS using both instruments. Not surprisingly the correlation between FPA and FWA remains positive and statistically significant.

Second, we use three less parsimonious models controlling for additional covariates with our original instrument. These regressors are likely to affect pricing decisions as well: labor share (proxy for technology) or import intensity (proxy for exchange rate fluctuations) or both in columns 3, 4 and 5 respectively in table 2.3. In all these cases we also find a positive and statistically significant relationship between FPA and FWA.[15] The F-statistic and the minimum eigenvalue do not seem to vary much compared to those in column 2.

We then repeat the same econometric strategy but now using as a dependent variable the frequency of adjustments of reference prices. Results are reported in table 2.4. Although the correlation is about half compared to that estimated with posted prices, it remains positive and statistically significant.

All in all, we find enough evidence to conclude that the frequency of price changes and the frequency of wage adjustments are positively correlated. That is, sectors changing more often their prices are also updating their wages more frequently. This correlation ranges approximately from 0.5 to 1. Consistent with price stickiness literature, this result implies heterogeneity in the frequency of wage variations, as it is observed in our data.

[15]Druant et al. [2012] and Dias et al. endorse the existence of a relationship between wage and price rigidity to the labor intensity characteristics of sectors. In their view, prices are more flexible when labor costs account for a lower fraction of firms' total costs. We obtain a similar result by finding a negative coefficient in columns 5 and 7 in table 2.3. Though, as shown before, labour intensity instruments poorly the FWA.

Figure 2.2: Frequency of adjustment: Wages and Earnings

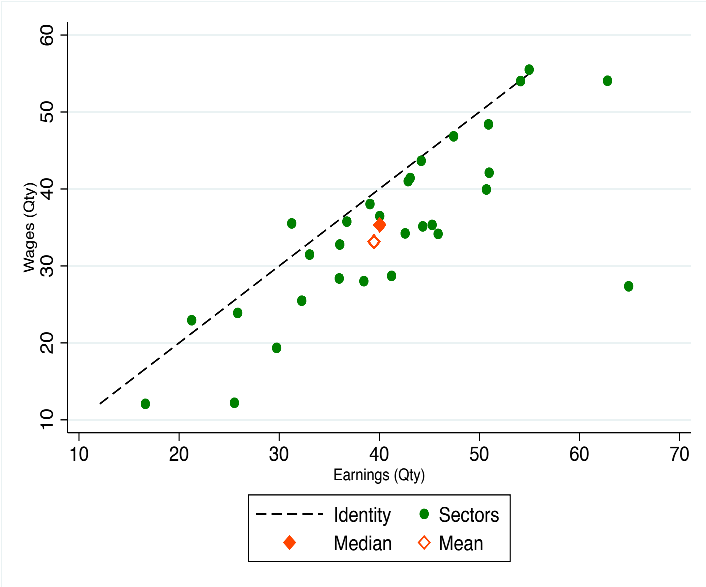


Table 2.1: Aggregate frequency of adjustment

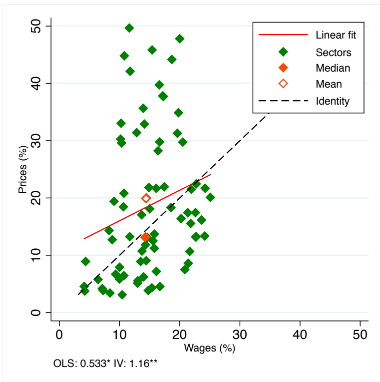
	Median		Mean	
	Frequency (%)	Implied Duration (Months)	Frequency (%)	Implied Duration (Months)
Posted Prices	13.16	7.09	19.94	4.50
Reference P (3m)	10.39	9.12	13.84	6.71
Wages	14.31	6.48	14.42	6.42
Earnings	18.81	4.80	17.55	5.18

Calvo parameters around the globe (monthly equivalent):
All prices: US 19.3%, France 19%;
Prices excluding sales: US 8.9%, UK 14%;
Wages: US 9.9%, France 14.7%

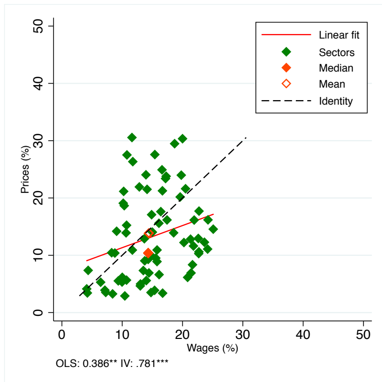
Table 2.2: Sectoral frequency of adjustment

	Frequency of Adjustment				
	Weight (%)	Posted Prices (%)	Ref Prices (%)	Wages (%)	Earnings (%)
Prepared meals	0.64	39.75	24.92	16.60	19.08
Coffee	0.23	33.04	21.15	10.25	19.08
Sugar ind	0.31	44.17	29.48	18.69	19.08
Livestock and poultry	7.23	45.83	27.58	15.41	19.08
Dairy products	4.52	37.82	23.39	17.19	19.08
Seafood packaging	0.26	42.11	26.34	11.76	19.08
Rice	0.23	49.66	30.55	11.62	19.08
Chocolate and others	0.16	37.71	23.79	17.29	19.08
Animal food	0.17	29.78	21.25	16.67	19.08
Fats and oils	0.48	47.80	30.35	20.00	19.08
Food (others)	1.42	29.60	18.66	10.34	19.08
Grain and seed milling	0.39	44.81	27.51	10.79	19.08
Bakery and tortilla	3.93	30.26	19.08	10.17	19.08
Tequila industry	1.11	32.89	21.51	14.13	17.30
Beer industry	2.21	31.28	20.17	19.62	17.30
Soft drinks industry	2.72	28.23	17.62	16.40	17.30
Tobacco industry	0.90	15.55	11.62	21.81	17.30
Other textile products	0.43	12.51	9.51	15.57	27.07
Cut and sew apparel	5.29	9.05	6.92	14.43	18.81
Footwear	2.24	8.91	7.34	13.50	14.18
Other leather products	0.13	7.91	6.15	10.01	14.18
Wooden products (excl furniture)	0.18	19.42	14.19	9.08	16.21
Furniture	1.40	20.83	15.24	10.73	18.93
Paper products	3.15	34.89	23.98	19.79	21.13
Newspaper and book printing	2.09	6.23	5.59	14.00	15.65
Fertilizers and pesticides	0.13	31.41	21.93	12.84	18.08
Pharmaceutical products	1.78	29.75	21.61	20.50	18.08
Soaps and cleaners	4.43	35.65	24.05	13.94	18.08
Lotion and perfumes	1.41	21.69	15.59	16.09	18.08
Candles and others	0.05	18.47	13.91	10.64	16.21
Chemical products (others)	0.06	8.61	6.91	21.42	18.08
Petroleum products (others)	0.22	18.12	14.04	15.01	14.74
Rubber products	0.20	21.83	17.08	14.88	19.56
Plastic products	0.06	16.39	12.22	20.23	19.56
Glass and glass products	0.13	17.45	12.94	22.62	27.90
Tools and utensils	0.28	21.95	16.17	17.43	21.40
Tools and utensils (others)	0.12	17.07	12.89	13.67	21.40
Computer equipment	0.34	10.67	8.35	21.66	22.92
Audio and video equipment	0.90	16.16	12.27	23.63	22.92
Magnetic and optical media	0.65	7.50	6.14	20.84	22.92
Household electrical app (others)	0.28	20.10	14.56	25.10	24.13
Batteries	0.06	21.51	16.15	21.93	24.13
Lighting accessories	0.07	17.43	12.81	21.33	24.13
Household electrical appliances	0.61	21.70	16.18	24.23	24.13
Motor vehicle parts	0.09	13.35	11.08	24.16	23.57
Other transport. equipment	0.03	13.70	10.92	15.78	23.57
Automobiles	4.98	22.46	17.71	22.74	23.57
Ophthalmic goods mfg	0.32	13.16	10.29	22.69	16.21
Photography equipment	0.15	13.10	10.11	14.63	18.93
Toys	0.66	11.22	8.90	15.77	16.21
Stationary	0.20	13.28	10.60	22.71	16.21
Dental offices	0.10	3.85	3.52	7.27	14.78
Other manufacturings	0.32	18.32	13.92	18.53	18.93
Water supply	1.12	13.25	10.91	11.69	12.29
Passenger transportation	6.54	6.69	5.53	9.35	12.24
Accounting services	0.27	4.54	3.39	16.70	21.27
Self-service and takeaways rest	10.31	11.83	9.28	14.31	20.07
Restaurants full service	0.63	5.78	5.30	6.43	20.07
Film and video industry	0.74	7.18	6.62	16.12	16.96
Nightclubs and similars	0.73	3.86	3.50	14.77	20.07
Recreational services	1.06	4.31	3.88	15.37	20.07
Automobile maintenance	0.73	6.45	5.66	10.72	16.32
Household goods repair	0.20	8.91	7.37	4.36	9.29
Beauty salons and clinics	0.83	4.57	4.14	4.12	9.29
Laundries and dry-cleaning	0.49	5.55	4.99	13.03	16.86
Real estate services	0.91	3.41	3.26	8.41	11.16
Funeral services	0.19	5.84	5.33	9.98	29.53
Domestic personnel	2.25	3.76	3.42	4.23	5.97
Parking vehicles services	0.05	3.11	2.91	10.44	14.94
Education services	7.56	10.73	9.04	13.73	14.20
Hospitalization services	2.96	4.18	3.91	7.13	14.78
Medical diagnostic	0.88	5.13	4.66	13.00	14.78
Nurseries	0.29	12.71	10.39	8.78	9.53
Governmental fees	0.82	14.32	10.44	8.26	7.67

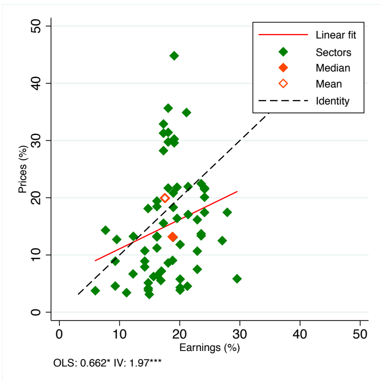
Figure 2.3: Frequency of adjustment



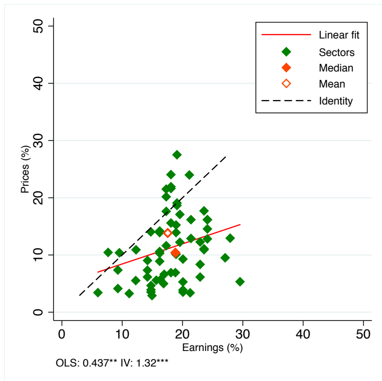
(a) Posted Prices and Wages



(b) Reference Prices and Wages

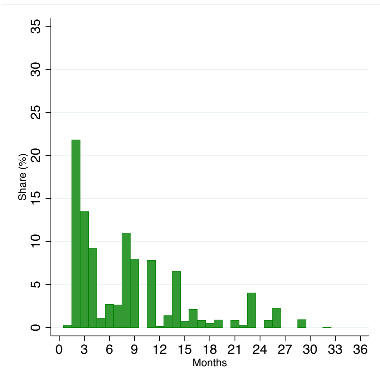


(c) Posted Prices and Earnings

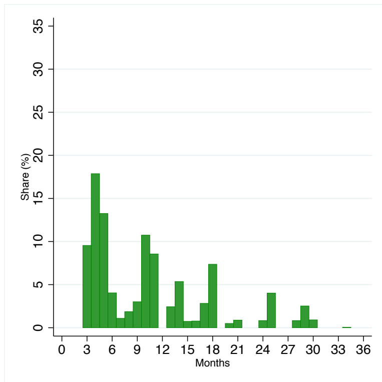


(d) Reference Prices and Earnings

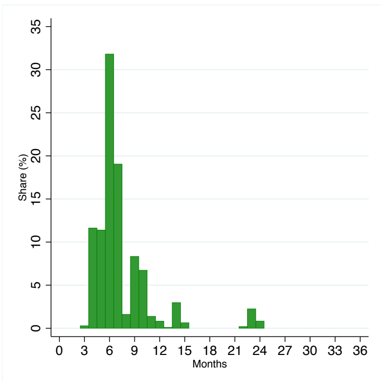
Figure 2.4: Distribution of implied durations



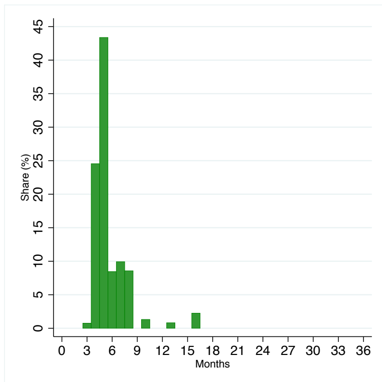
(a) Posted Prices



(b) Reference Prices



(c) Wages



(d) Earnings

Table 2.3: IV: Frequency of posted price and wage adjustments

	(1)	(2)	(3)	(4)	(5)
	OLS	IV	IV	IV	IV
VARIABLES	Posted P	Posted P	Posted P	Posted P	Posted P
Freq Wage Adj	0.533**	0.964***	0.779**	0.978**	1.162**
	(0.224)	(0.277)	(0.334)	(0.392)	(0.463)
Labor Share			-0.246***		-0.374***
			(0.058)		(0.070)
Import Intensity				-0.005	-0.186***
				(0.071)	(0.064)
Constant	0.107***	0.042	0.123**	0.043	0.178**
	(0.038)	(0.043)	(0.061)	(0.041)	(0.077)
Observations	74	74	74	74	74
R-squared	0.048	0.017	0.191	0.015	0.202
IV		MW Sh	MW Sh	MW Sh	MW Sh
Adj R2		0.534	0.598	0.616	0.622
Robust F		48.939	67.257	32.391	41.558
Min Eig		84.554	86.393	65.909	68.563

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.4: IV: Frequency of reference price and wage adjustments

	(1)	(2)	(3)	(4)	(5)
	OLS	IV	IV	IV	IV
VARIABLES	Ref P	Ref P	Ref P	Ref P	Ref P
Freq Wage Adj	0.386***	0.675***	0.564***	0.673***	0.781***
	(0.134)	(0.170)	(0.201)	(0.236)	(0.275)
Labor Share			-0.148***		-0.220***
			(0.035)		(0.041)
Import Intensity				0.001	-0.105***
				(0.042)	(0.038)
Constant	0.075***	0.031	0.080**	0.031	0.111**
	(0.022)	(0.026)	(0.036)	(0.025)	(0.045)
Observations	74	74	74	74	74
R-squared	0.070	0.031	0.208	0.031	0.208
IV		MW Sh	MW Sh	MW Sh	MW Sh
Adj R2		0.534	0.598	0.616	0.622
Robust F		48.939	67.257	32.391	41.558
Min Eig		84.554	86.393	65.909	68.563

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

2.5 Absolute size of price and wage adjustments

We present in this section features from the distribution of the absolute size of price and wage adjustments (given a non-zero change). Similarly as in the previous section, we describe aggregate weighted statistics and we then provide a sectoral comparison between prices and wages. We neglect from this section earnings data due to measurement errors.[16]

Prices' and wages' absolute size of (non-zero) adjustments of are important for a number of reasons. First, we consider absolute values because we do not want positive and negative changes to average out. Second, it is well stablished that both goods' and labour's prices often remain fixed for a number of periods, followed by a not negligible variation. Thus, we neglect the overwhelming number of zeros in our sample. In other words, these are the absolute size of adjustments conditional on a price/wage change. Third, from the theoretical point of view, the size of the adjustment is often viewed as indicative on how and when cost inflation pressure is released. In other words, how willing are firms to deviate from their optimal price i.e. the so-called S,s area.

2.5.1 Aggregate size of adjustment

Table 2.5 reports the aggregate weighted median and mean of the absolute size of adjustment for posted and reference prices, as well as wages. The aggregate median is calculated by first calculating the unweighted mean of price and wage changes in absolute terms within each sector; and then taking a weighted median across sectors using CPI expenditure weights. Likewise, the aggregate mean is computed as the weighted mean across sectors from unweighed sectoral means.

The differences between the mean and median for our two different measures of prices changes is small. For posted prices the median is 7.16% and the mean is 7.21%. In the case of reference prices 8.13% and 8.00% are the median and mean respectively. The fact that posted prices' first moments are smaller than their reference prices' counterparts implies that transitory discounts (included in our posted prices measure) are smaller, on average, than non-transitory price variations.

The median and mean of the absolute size of wage adjustments are almost identical, 3.25% and 3.26%. Noticeably, these values are very close to the inflation target set by the Mexican Central Bank at 3%; and less than the average increase

[16]Fitting an error band as in the frequency of adjustment section is a good bypass for controlling for measurement errors in binary outcomes. For the size of adjustments, in contrast, fitting an error band does not reduce (likely) misreporting.

of the minimum wage in our sample period which was 4%.

2.5.2 Sectoral size of adjustment

Sectorial data about the absolute size of price and wage adjustments is listed in table 2.6. Figure 2.5a and figure 2.5b depict data points from this table.

The absolute size of adjustments is positively correlated across sectors. In other words, industries with large price swings are also industries exhibiting greater wage updates. A simple OLS regression across the 74 industries reports a correlation of 0.798** for posted prices and 0.809** for reference prices against wage adjustments. In contrast with the frequency of adjustment, however, the positive correlation across the absolute size of adjustments across industries is not robust. If we omit from the sample the top and bottom 2 sectors with respect to the size of price adjustments, the simple OLS results becomes insignificant. See figure 2.14a and figure 2.14b in the Appendix for more.

For completeness we follow the same strategy as in the frequency of adjustments and calculate an IV estimator. Table 2.6 and table 2.8 summarise these results for posted and reference prices respectively. We find that the size of adjustments are also positively correlated under IV estimation. For posted prices the IV estimator with respect wages is 1.73*** and for reference prices is 1.62***

Compared to the heterogeneity in the frequency adjustments, figures 2.5a and 2.5b show that the size of price changes is heterogeneous across industries, while the size is wage changes has considerably lower variance.

Table 2.5: Aggregate absolute size of adjustment

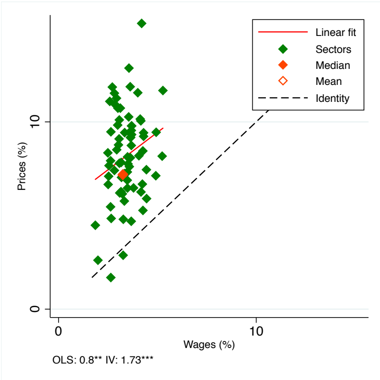
	Median (%)	Mean (%)
Posted Prices	7.16	7.21
Reference P (3m)	8.13	8.00
Wages	3.25	3.26

Notes. Unweighted statistics within sectors.
Weighted statistics between sectors.

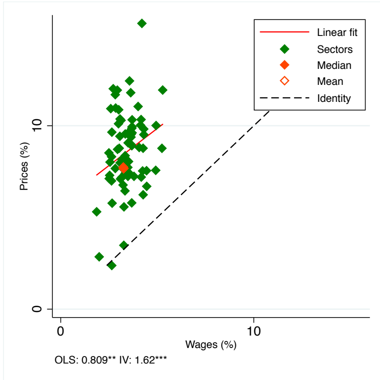
Table 2.6: Sectoral absolute size of adjustment

	Absolute Size of Adjustment			
	Weight (%)	Posted Prices (%)	Ref Prices (%)	Wages (%)
Prepared meals	0.64	6.47	7.28	3.49
Coffee	0.23	5.27	6.24	4.27
Sugar ind	0.31	7.20	8.37	3.34
Livestock and poultry	7.23	7.16	7.83	3.25
Dairy products	4.52	5.77	6.45	3.33
Seafood packaging	0.26	5.90	6.70	4.45
Rice	0.23	8.13	9.07	3.49
Chocolate and others	0.16	6.27	7.18	3.16
Animal food	0.17	7.76	8.05	3.51
Fats and oils	0.48	6.21	7.10	3.09
Food (others)	1.42	6.68	7.54	4.24
Grain and seed milling	0.39	6.47	7.24	3.79
Bakery and tortilla	3.93	6.26	7.20	4.17
Tequila industry	1.11	4.80	5.58	3.28
Beer industry	2.21	4.48	5.31	1.86
Soft drinks industry	2.72	6.89	7.73	3.48
Tobacco industry	0.90	5.46	6.99	2.63
Other textile products	0.43	10.74	10.29	3.13
Cut and sew apparel	5.29	10.27	9.67	3.55
Footwear	2.24	7.61	7.37	3.58
Other leather products	0.13	11.56	11.05	4.01
Wooden products (excl furniture)	0.18	10.15	10.03	4.13
Furniture	1.40	8.74	8.91	3.68
Paper products	3.15	8.51	8.71	2.94
Newspaper and book printing	2.09	7.79	7.98	3.08
Fertilizers and pesticides	0.13	9.18	9.53	3.65
Pharmaceutical products	1.78	6.66	7.12	2.51
Soaps and cleaners	4.43	7.83	8.16	3.17
Lotion and perfumes	1.41	10.73	10.87	3.00
Candles and others	0.05	9.45	10.01	4.94
Chemical products (others)	0.06	9.42	9.82	4.30
Petroleum products (others)	0.22	7.04	7.70	3.18
Rubber products	0.20	7.24	7.41	3.34
Plastic products	0.06	11.53	11.69	2.83
Glass and glass products	0.13	11.10	10.93	2.59
Tools and utensils	0.28	8.77	8.77	3.03
Tools and utensils (others)	0.12	11.88	11.80	3.63
Computer equipment	0.34	7.67	8.02	2.55
Audio and video equipment	0.90	8.35	8.52	2.50
Magnetic and optical media	0.65	10.95	10.97	2.85
Household electrical app (others)	0.28	7.93	8.31	2.63
Batteries	0.06	11.26	11.94	2.93
Lighting accessories	0.07	11.86	12.02	2.72
Household electrical appliances	0.61	7.41	7.67	2.83
Motor vehicle parts	0.09	7.10	7.29	2.53
Other transport. equipment	0.03	8.45	8.77	4.27
Automobiles	4.98	2.61	2.85	1.99
Ophthalmic goods mfg	0.32	9.47	9.65	2.65
Photography equipment	0.15	9.43	9.55	3.34
Toys	0.66	9.79	9.94	3.69
Stationary	0.20	9.83	10.11	2.99
Dental offices	0.10	9.23	9.52	4.30
Other manufacturings	0.32	9.09	9.42	3.06
Water supply	1.12	2.88	3.48	3.27
Passenger transportation	6.54	8.08	8.99	3.64
Accounting services	0.27	26.12	18.86	2.37
Self-service and takeaways rest	10.31	6.16	6.77	3.23
Restaurants full service	0.63	7.45	7.55	4.45
Film and video industry	0.74	7.33	7.24	3.48
Nightclubs and similars	0.73	9.32	9.61	3.70
Recreational services	1.06	12.87	12.44	3.56
Automobile maintenance	0.73	9.54	9.86	3.68
Household goods repair	0.20	8.17	8.77	5.24
Beauty salons and clinics	0.83	11.68	11.94	5.28
Laundries and dry-cleaning	0.49	9.16	9.38	3.64
Real estate services	0.91	10.06	10.34	4.16
Funeral services	0.19	7.13	7.57	4.92
Domestic personnel	2.25	8.19	8.81	4.07
Parking vehicles services	0.05	15.26	15.58	4.20
Education services	7.56	4.84	5.78	2.66
Hospitalization services	2.96	9.79	10.32	3.70
Medical diagnostic	0.88	10.11	10.37	3.07
Nurseries	0.29	4.69	5.79	3.68
Governmental fees	0.82	1.69	2.38	2.65

Figure 2.5: Absolute size of adjustment



(a) Posted Prices and Wages



(b) Reference Prices and Wages

Table 2.7: IV: Absolute size of posted price and wage adjustments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	2SLS	IV	IV	IV
VARIABLES	Posted P	Posted P	Posted P	Posted P	Posted P	Posted P	Posted P
Size Wage Adj	0.800*	1.106**	0.657	1.085**	1.138**	1.703***	1.733***
	(0.419)	(0.462)	(2.209)	(0.481)	(0.470)	(0.479)	(0.510)
Labor Share					-0.004		0.026
					(0.019)		(0.018)
Import Intensity						0.028***	0.039***
						(0.011)	(0.009)
Constant	0.054***	0.044***	0.059	0.045***	0.044***	0.011	-0.001
	(0.015)	(0.017)	(0.075)	(0.017)	(0.017)	(0.019)	(0.020)
Observations	74	74	74	74	74	74	74
R-squared	0.054	0.046	0.052	0.047	0.045	0.094	0.118
IV		MW Sh	Labor Share	MW Sh	MW Sh	MW Sh	MW Sh
IV2		.	.	Labor Share	.	.	.
Adj R2		0.491	0.042	0.493	0.493	0.485	0.487
Robust F		18.307	3.155	17.763	17.291	16.087	18.920
Min Eig		70.478	4.167	36.067	64.254	57.608	58.274

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.8: IV: Absolute size of reference price and wage adjustments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	2SLS	IV	IV	IV
VARIABLES	Ref 3m P	Ref 3m P	Ref 3m P	Ref 3m P	Ref 3m P	Ref 3m P	Ref 3m P
Size Wage Adj	0.809**	1.100***	0.611	1.078**	1.135***	1.599***	1.622***
	(0.390)	(0.425)	(2.086)	(0.447)	(0.424)	(0.436)	(0.463)
Labor Share					-0.005		0.020
					(0.018)		(0.017)
Import Intensity						0.023**	0.032***
						(0.010)	(0.009)
Constant	0.058***	0.048***	0.065	0.049***	0.048***	0.020	0.011
	(0.014)	(0.015)	(0.071)	(0.016)	(0.015)	(0.017)	(0.019)
Observations	74	74	74	74	74	74	74
R-squared	0.067	0.058	0.063	0.059	0.058	0.096	0.112
IV		MW Sh	Labor Share	MW Sh	MW Sh	MW Sh	MW Sh
IV2		.	.	Labor Share	.	.	.
Adj R2		0.491	0.042	0.493	0.493	0.485	0.487
Robust F		18.307	3.155	17.763	17.291	16.087	18.920
Min Eig		70.478	4.167	36.067	64.254	57.608	58.274

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

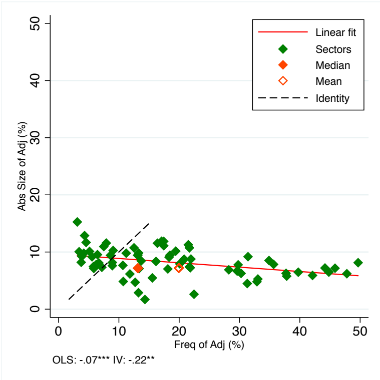
2.6 Frequency and size of price and wage changes

We now turn to relating the extensive and intensive margins of our price and wage statistics. Figure 2.6a and figure 2.6b show a weak negative relationship between the absolute size and frequency of adjustments for price data. In the context of menu-cost theory, sectors with higher adjustment cost tend to change less frequently prices, however when they do change their prices they do it by a larger magnitude. This result supports some of the foundations in state-dependent pricing frameworks.

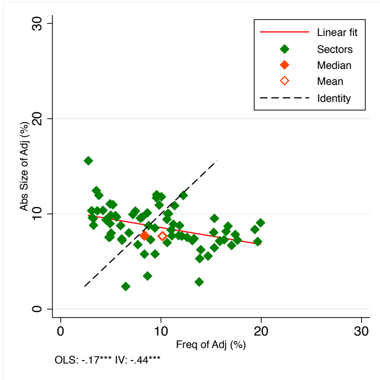
A novelty from this research is to find a similar pattern for wages, as illustrated in figure 2.6c. From this figure, we observe large heterogeneity on the frequency of wage changes. This finding is similar to what has been widely documented in price data. A striking point is the relatively low degree of heterogeneity on the intensive margin of wages as noted in the previous section.

The heterogeneous extensive margin and homogeneous intensive margin on the wage data implies a number of things from the menu-cost point of view. One thing is that the menu-cost seems to be homogeneous across industries. Hence, given a wage change, it changes approximately by the same amount regardless the sector. Another implications is that the deviation from the optimal wage is what varies across industries. If some sectoral wages deviate faster from their optimal level than

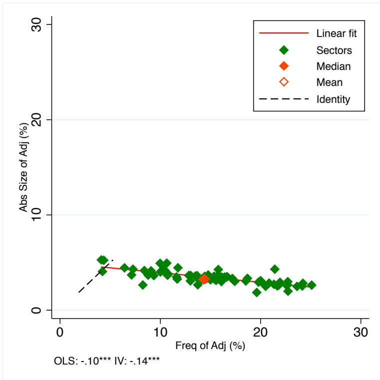
Figure 2.6: Absolute size and frequency of adjustment



(a) Posted Prices



(b) Reference Prices



(c) Wages

in other sectors (keeping the menu-cost equal for all), they end up producing the outcome in graph 2.6c.

2.7 Distribution of (non-zero) price and wage changes

We finish the empirical part of this chapter by characterising the complete distribution of monthly (log) non-zero changes of posted prices, reference prices and wages. Figure 2.7 shows the distribution for our three variables of interest.

The distributions are somewhat similar. First, distributions' kurtosis is quite large: the 0%-1% range is the greatest for the three distributions, remarkably different though. For the wage distribution the 0%-1% bin is more than 20%, whereas for prices is only about 7%.

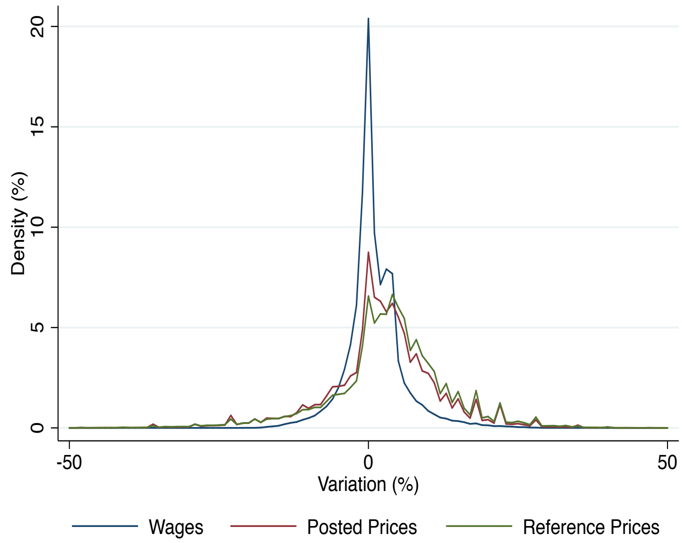
Also, the three distributions have a small hump out away from the mode. For price distributions these humps are situated around the 5% bin. For the case of wages, the hump coincides with the average annual increase of the minimum wage in our sample period, that is 4%.

Common marketing strategies, -5%, -10% and -25% price drops, are observed in the distribution. Similarly, we note clusters of observations in positive bins around natural sales recoveries or typical rounding increases observed in services

In terms of the tails of the distributions, price distributions exhibit fatter tails. The bottom 10 percentile for both of the price distributions is -8%, whereas the top 10 percentile is 13% for posted prices and 15% for reference prices. The bottom 10 percentile for the wage distribution is -4% and the top 10 percentile is 6%.

Strikingly, the distribution of wage changes shows less downward nominal rigidities than in similar datasets from developed economies. Around 20% of wage variations are negative. Indeed, Castellanos et al. [2004] find evidence that magnitude of downward nominal wage rigidities has significantly fallen since the tequila crisis in 1994.

Figure 2.7: Distribution of non-zero changes



2.8 Price and wage heterogeneity in a New Keynesian model

Our empirical analysis suggests that (i) the frequency of price adjustment is positively correlated with the frequency of wage updates across different industries; (ii) wage stickiness is greater than the stickiness of reference prices but lower than posted prices rigidity; (iii) frequency of adjustments is heterogeneous across industries for both prices and wages; (iv) absolute size of price adjustments is heterogeneous for prices but not for wages; and (v) frequency and size of adjustments are negatively correlated, not only for prices but for wages as well. To our knowledge, this is the first paper documenting these patterns between prices and wages.

We use a standard DSGE model that can encompass as many of our empirical results as possible. To that end, we use a model in which firms use a constant returns to scale technology, and firms (unions) set prices (wages) a-la-Calvo respectively.

In order to incorporate the heterogeneity in the frequency of price and wage changes we extend Carvalho [2006] multi-sector economy in two directions. First, we introduce sticky wages. In contrast to Carvalho [2006], who use flexible wages, we use sector-specific Calvo-wage parameters. Thus, each sector is characterised by one sector-specific Calvo parameter for prices and one sector-specific Calvo parameter for wages. We refer to this sectoral calibration as "Calvo pairs".

Second, we allow for sector-specific labor. That is, firms in sector k employ only households in sector k and there is no labor mobility across sectors.[17] Thus, her wage depends on the sector-specific wage rigidity as well as demand for the sector's production (which depends on relative prices). This specification allows for having wage (and cost) differentials across sectors. If labor was not sector-specific, then our heterogeneous Calvo-wages characterisation would be irrelevant.

Additionally, households consume a composite good from all sectors. Thus, income is sector-specific but households care about their purchasing power across sectors.

Our model presents a number of limitations embedding all the empirical results presented in the previous section. Primarily, our model relies on a time-dependent price- and wage-setting framework based on Calvo (1983). In this framework, a fixed proportion of firms/households reset their prices/wages, every period, to its optimal level. This proportion of agents adjusting their prices is interpreted as the frequency of adjustment. As we make use of a multi-sector economy, we can embed the complete distribution of price-wage frequencies across industries, including its correlation. Thus, we are able to study the implications of findings (i), (ii), (iii). The use of a state-dependent pricing and wage-setting framework would be required to embed the remaining findings. However, these type of models have

[17] Although in reality a worker may shift sectors, one can think of a worker who has developed certain skill and therefore it is difficult for her to shift sectors. An alternative would be to incorporate certain cost in shifting sectors. However, the later approach would only dilute the effect of sticky wages.

different properties and further complicate the already complex DSGE model. We opt to follow a more standard price-setting and wage-setting framework used in New Keynesian (NK) literature.

It is worth mentioning that it is not our intention to fit a model for the Mexican economy. Instead, we study the implications of the distribution of adjustments' frequencies across industries for monetary policy.

Also, in order not to further confuse the multi-sector economy presented below, we abstract from other traditional channels found in the NK literature. For instance, we do not consider price and wage indexation, nor firms' capital accumulation, nor habit formation. The first channel is at odds with microdata evidence. Indexation implies that every period all firms and unions reset their prices, something we do not observe in our data. The second channel, depending if it is sector-specific or not, would only dilute the effect of wages on the total production cost, and therefore on prices. The third channel is used to gain persistence on the effects of monetary policy, whereas in our case we are interested to analyse what are the implication of using a realistic Calvo distribution in an otherwise standard NK model.

In what follows, we outline the main departures from the original Carvalho [2006] model. The curious reader can refer to the original paper for more details about the model. In the next subsection we present the calibration as well as our approach for analysing the implications of using the actual Calvo-distribution i.e. the set of Calvo pairs governing prices and wages in the multi-sector economy.

2.8.1 Multi-Calvo Economy

We use a multi-sector economy with a constant-returns to scale technology following Carvalho [2006]. Labor market is sector specific. Prices and wages are set à-la-Calvo. Each sector has its own price and wage parameters based on table 2.2.

Sectoral split

Assume a continuum of firms indexed by $kj \in [0,1]^2$. There are j-type firms in every sector k. Firms and sectors can be described as

$$\int_0^1 \int_0^1 f(k,j)dj dk = \int_0^1 f(k)dk = 1; \quad kj \in [0,1]^2$$

Firms and price setting

Firm kj hires labor of its specific type to produce its variety of consumption goods. All firms have an identical linear technology represented by the production function:

$$Y_{kj,t} = N_{kj,t} \tag{2.1}$$

where $Y_{kj,t}$ is the production of its variety and $N_{kj,t}$ is the specific labor input.

Firms reset their prices following Calvo [1983]. That is, each firm kj may reset its price only with probability λ_k^p in any given period, regardless the time elapsed since its last price update. When firm kj resets its price, it solves the following maximisation problem

$$\max_{P^*_{kj,t}} \; E_t \sum_{s=0}^{\infty} Q_{t,t+s} \left(1-\lambda_k^p\right)^s \left[P^*_{kj,t} Y_{kj,t+s} - W_{kj,t+s} N_{kj,t+s}\right]$$

$$\text{subject to} \quad Y_{kj,t+s} = \left(\frac{P^*_{kj,t}}{P_{t+s}}\right)^{-\varepsilon_p} Y_{t+s}$$

The stochastic nominal discount factor between period t and $t+s$ for pricing firms profits, $Q_{t,t+s}$, is given by equation 2.12 as

$$Q_{t,t+s} = \beta^s \left(\frac{C_{t+s}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+s}}$$

The optimality condition associated with the problem above takes the form

$$\sum_{s=0}^{\infty} \left(1-\lambda_k^p\right)^s E_t \left[Q_{t,t+s} Y_{t+s} \left(P^*_{kj,t} - \mathcal{M}_p \, W_{kj,t+s}\right)\right] = 0 \tag{2.2}$$

where $\mathcal{M}_p = \frac{\varepsilon}{\varepsilon-1}$ is the price markup.

Since the distribution of future nominal wages $W_{kj,t+s}$ conditional on time-t information is the same for all firms changing prices in sector k, all firms in sector k choose the same nominal price $P^*_{k,t}$

Next, the optimal price setting in sector k in equation 2.2 is log-linearised around the perfect foresight zero inflation steady state. Thus, a first order Taylor expansion and omitting the constant markup yields

$$p_{k,t}^{*}=\left(1-\beta\left(1-\lambda_{k}^{p}\right)\right)\sum_{s=0}^{\infty}\beta^{s}\left(1-\lambda_{k}^{p}\right)^{s}w_{k,t+s} \tag{2.3}$$

As only a fraction λ_k^p of firms in sector k change their prices every period, the sectoral price index can be written as

$$p_{k,t}=\lambda_{k}^{p}p_{k,t}^{*}+\left(1-\lambda_{k}^{p}\right)p_{k,t-1} \tag{2.4}$$

Finally, a log-linearised version of the price index is the weighted sum of sectoral price indices

$$p_{t}=\int_{0}^{1}f(k)p_{k,t}dk \tag{2.5}$$

Households and wage setting

We assume a continuum of monopolistically competitive households (indexed, likewise firms, by the $kj\in[0,1]^{2}$), each of which supplies differentiated labor to firms. Firms regard each household's labor N_{kj}, $j\in[0,1]$ as an imperfect substitute for labor of other households in sector k. Thus, the representative household kj supplies labor and solves

$$E\sum_{t=0}^{\infty}\beta^{t}\left(\frac{C_{t}^{1-\sigma}-1}{1-\sigma}-\int_{0}^{1}\frac{N_{kj,t}^{1+\varphi}}{1+\varphi}dj\right)$$

$$\text{subject to}\qquad P_{t}C_{t}=\int_{0}^{1}N_{kj,t}W_{kj,t}dj+B_{t-1}-Q_{t,t+1}B_{t}+T_{k,t}$$

where β is the discount factor, C_t is consumption of a composite good, $N_{kj,t}$, $W_{kj,t}$ are the supplied quantity and associated nominal wage of type kj labor respectively and $T_{k,t}$ are firms' profits received by the consumer through lump-sum transfers in sector k. Moreover, B_t denotes bond holding earning interest at rate $Q_{t,t+1}^{-1}$ and P_t is the price index defined below. The parameters σ and φ determine the curvature of the utility of consumption and the disutility of labor respectively.

Composite goods are defined as

$$C_{t}\equiv\left[\int_{0}^{1}f\left(k\right)^{\frac{1}{\varepsilon_{p}}}C_{k,t}^{\frac{\varepsilon_{p}-1}{\varepsilon_{p}}}dk\right]^{\frac{\varepsilon_{p}}{\varepsilon_{p}-1}} \tag{2.6}$$

$$C_{k,t} \equiv \left[f(k)^{\frac{-1}{\varepsilon_p}} \int_0^1 C_{kj,t}^{\frac{\varepsilon_p - 1}{\varepsilon_p}} dj \right]^{\frac{\varepsilon_p}{\varepsilon_p - 1}} \tag{2.7}$$

where $C_{k,t}$ and $C_{kj,t}$ are the subcomposite of goods produced by firms in sector k and the variety of the good produced by firm j from sector k respectively. The elasticity of substitution between consumption varieties is $\varepsilon_p > 1$.[18] Prices in the economy are given by

$$P_t = \left[\int_0^1 f(k) P_{k,t}^{1-\varepsilon_p} dk \right]^{\frac{1}{1-\varepsilon_p}} \tag{2.8}$$

$$P_{k,t} = \left[f(k)^{-1} \int_0^1 P_{kj,t}^{1-\varepsilon_p} dj \right]^{\frac{1}{1-\varepsilon_p}} \tag{2.9}$$

Given these expressions, the first order conditions for the representative consumer kj are

$$C_{k,t} = f(k) C_t \left(\frac{P_{k,t}}{P_t} \right)^{-\varepsilon_p}, \quad k \in [0,1] \tag{2.10}$$

$$C_{kj,t} = f(k)^{-1} C_{k,t} \left(\frac{P_{kj,t}}{P_{k,t}} \right)^{-\varepsilon_p}, \quad kj \in [0,1]^2 \tag{2.11}$$

$$Q_{t,t+1} = \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \right\} \tag{2.12}$$

$$\frac{W_{kj,t}}{P_t} = \frac{N_{kj,t}^{\varphi}}{C_t^{-\sigma}} \tag{2.13}$$

$$\frac{W_{k,t}}{P_t} = \frac{N_{k,t}^{\varphi}}{C_t^{-\sigma}} \tag{2.14}$$

where equation 2.14 is obtained by integrating equation 2.13 over j.

We can represent in log-linearised form (abstracting constant terms) expression 2.12 as

$$c_t = E_t(c_{t+1}) - \frac{1}{\sigma}(i_t - E_t(\pi_{t+1}^p)) \tag{2.15}$$

where $\pi_{t+1}^p \equiv p_{t+1} - p_t$

Let us now move to consider how households, specialised in a given labor type and sector, set their wages. Goods are produced using labor as their only input.

[18] Carvalho [2006] argues that allowing the elasticity of substitution between the sectoral subcomposites (equation 2.6) to differ from the within sector elasticity of substitution (equation 2.7) do not change the overall dynamics of the model.

Production is a (constant elasticity of substitution) aggregate of a continuum types of labor supplied by the representative household in sector k, defined by

$$N_{k,t} = \left[\int_0^1 N_{kj,t}^{\frac{\varepsilon_w - 1}{\varepsilon_w}} dj \right]^{\frac{\varepsilon_w}{\varepsilon_w - 1}} \tag{2.16}$$

It follows that the demand for labor type j in sector k on the part of wage taking firms is given by

$$N_{kj,t} = \left(\frac{W_{kj,t}}{W_{k,t}} \right)^{-\varepsilon_w} N_{k,t} \tag{2.17}$$

Wage rigidities are introduced in an analogous way to the goods' market. That is, workers in sector k reset their wage with probability λ_k^w, independently of the time elapsed since they last adjusted their wage. The workers' union chooses wages in a way consistent with utility maximisation of its members households, taking as given the decision of the other unions as well as the path for the aggregate consumption and prices. The union in sector k seeks to maximise

$$\max_{W_{kj,t}^*} E_t \sum_{s=0}^{\infty} \left[\beta \left(1 - \lambda_k^w \right) \right]^s \left(C_{t+s}^{-\sigma} \frac{W_{kj,t}^*}{P_{t+s}} N_{kj,t+s|t} - \frac{N_{kj,t+s|t}^{1+\varphi}}{1+\varphi} \right) \tag{2.18}$$

$$\text{subject to} \quad N_{kj,t+s|t} = \left(\frac{W_{kj,t}^*}{W_{k,t+s}} \right)^{-\varepsilon_w} N_{k,t+s}$$

The first order condition associated with the problem above is given by

$$\sum_{s=0}^{\infty} \left[\beta \left(1 - \lambda_k^w \right) \right]^s E_t \left\{ N_{kj,t+s|t} C_{t+s}^{-\sigma} \left(\frac{W_{kj,t}^*}{P_{t+s}} - \mathcal{M}_w \mathcal{MRS}_{kj,t+s|t} \right) \right\} = 0 \tag{2.19}$$

where $\mathcal{M}_w = \frac{\varepsilon_w}{1-\varepsilon_w}$ is the desired wage markup and $\mathcal{MRS}_{kj,t+s|t} = C_t^{\sigma} N_{kj,t+s|t}^{\varphi}$ is the marginal rate of substitution between household consumption and employment in period $t+s$ relevant to the worker reseting their wage at time t.

Log-linearising equation 2.19 and omitting the constant markup, we get optimal wage in sector k as

$$w_{kj,t}^* = \left(1 - \beta \left(1 - \lambda_k^w \right) \right) \sum_{s=0}^{\infty} \beta^s \left(1 - \lambda_k^w \right)^s \left(p_{t+s} + mrs_{kj,t+s|t} \right) \tag{2.20}$$

Letting $mrs_{kj,t+s|t} = mrs_{kj,t+s} - \varepsilon_w \varphi (w_{kj,t}^* - w_{k,t})$, with $mrs_{kj,t+s} = \sigma c_{t+s} +$

$\varphi n_{kj,t+s}$ from expression 2.13, we can rewrite equation 2.20 as

$$w_{kj,t}^{*} = \frac{\left(1-\beta\left(1-\lambda_{k}^{w}\right)\right)}{1+\varphi\varepsilon_{w}} \left\{ \sum_{s=0}^{\infty} \left[\beta\left(1-\lambda_{k}^{w}\right)\right]^{s} \left(p_{t+s}+\sigma c_{t+s}+\varphi\left(\varepsilon_{w} w_{k,t+s}+n_{k,t+s}\right)\right) \right\} \tag{2.21}$$

We can abstract the subscript j since unions reseting their wages in sector k choose the same wage within the sector. In line with our budget constraint, wages depend positively in the overall price index, aggregate consumption, as well as sectoral wage and labor demand (see equation 2.13).

Analogous to sectoral price indices, wage in sector k can be written as

$$w_{k,t} = \lambda_{k}^{w} w_{k,t}^{*} + \left(1-\lambda_{k}^{w}\right) w_{k,t-1} \tag{2.22}$$

Equilibrium

The goods market clearing condition requires $Y_t = C_t$, in logs

$$y_t = c_t \tag{2.23}$$

This last expression also determines the sectoral demand as

$$y_{k,t} = y_t - \varepsilon_p (p_{k,t} - p_t) \tag{2.24}$$

To close the model, we specify the interest rate rule followed by the monetary authority. This is done by postulating an interest rate rule of the form

$$i_t = \phi_\pi \pi_t + \phi_y y_t + v_t \tag{2.25}$$

where ϕ_π and ϕ_y are the standard parameters associated with Taylor-type interest rate rules, and $v_t = \kappa v_{t-1} + \xi_t$ is a zero mean, finite variance i.i.d process.

Fully specified model

We summarise the full set of equations that characterise the log-linear approximation of the model around its deterministic zero inflation steady state. Lower case variables denote log deviations from the zero inflation steady state.

$$w_{k,t}^{*}=\frac{(1-\beta(1-\lambda_{k}^{w}))}{1+\varphi\varepsilon_{w}}\left\{\sum_{s=0}^{\infty}(\beta(1-\lambda_{k}^{w}))^{s}(p_{t+s}+\sigma y_{t+s}+\varphi\varepsilon_{w}w_{k,t+s}+\varphi y_{k,t+s})\right\} \tag{2.26}$$

$$w_{k,t}=\lambda_{k}^{w}w_{k,t}^{*}+(1-\lambda_{k}^{w})\,w_{k,t-1} \tag{2.27}$$

$$p_{k,t}^{*}=\left(1-\beta\left(1-\lambda_{k}^{p}\right)\right)\sum_{s=0}^{\infty}\beta^{s}\left(1-\lambda_{k}^{p}\right)^{s}w_{k,t+s} \tag{2.28}$$

$$p_{k,t}=\lambda_{k}^{p}p_{k,t}^{*}+\left(1-\lambda_{k}^{p}\right)p_{k,t-1} \tag{2.29}$$

$$p_{t}=\int_{0}^{1}f(k)p_{k,t}dk \tag{2.30}$$

$$\pi_{t}=p_{t}-p_{t-1} \tag{2.31}$$

$$y_{t}=E_{t}y_{t+1}-\frac{1}{\sigma}(i_{t}-E_{t}\pi_{t+1}) \tag{2.32}$$

$$y_{k,t}=y_{t}-\varepsilon_{p}(p_{k,t}-p_{t}) \tag{2.33}$$

$$y_{kj,t}=c_{kj,t}=n_{kj,t} \tag{2.34}$$

$$c_{t}=y_{t} \tag{2.35}$$

$$i_{t}=\phi_{\pi}\pi_{t}+\phi_{y}y_{t}+v_{t} \tag{2.36}$$

$$v_{t}=\kappa v_{t-1}+\xi_{t} \tag{2.37}$$

Calibration

We begin our calibration by taking standard values from the New Keynesian literature for monthly calibrations. Following Carvalho [2006] and Rudebusch [2002], we assume $\beta = 0.9975$, which implies a 3% annual interest rate. The parameters for the monetary policy rule are $\kappa = 0.95$, $\phi_\pi = 1.24$ and $\phi_y = 0.33/12$.

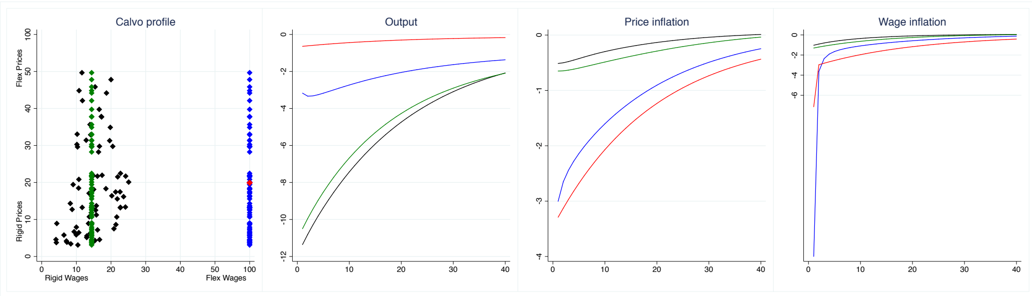
We set $\varphi = 5$, implying that intertemporal labor supply elasticity of 0.2. Dixon and Kara [2011] set a fairly similar value of $\varphi = 4.5$ for a Generalised Taylor Economy. Smets and Wouters [2003] fit a posterior of $\varphi = 2.4$ for an homogeneous Calvo economy with indexation and habit formation.

The demand elasticity due to sectoral relative prices ε_p is set at 11. This is the same as one of the calibrations used by Carvalho [2006]; Galí [2015] sets $\varepsilon_p = 9$; and Dixon and Kara [2010] set $\varepsilon_p = 12$. See Dixon and Kara [2010] and the references therein for more instances using similar calibrations to ours for ε_p. We use $\varepsilon_w = 2.5$. Smets and Wouters [2003] set $\varepsilon_w = 3$ and Galí [2015] uses $\varepsilon_w = 4.5$.

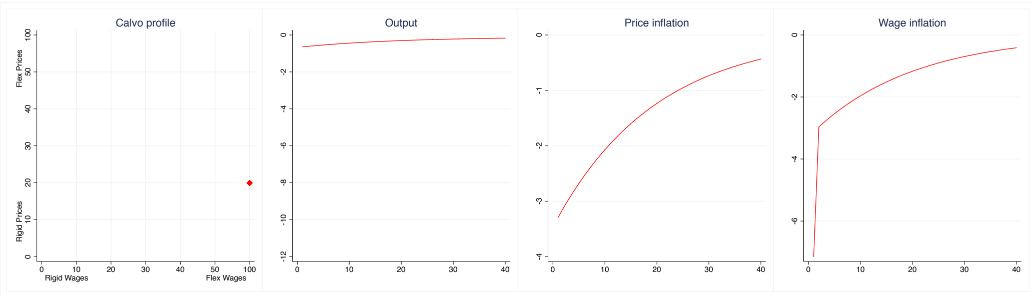
Thus, the parameters' configuration is well within the ranges found in the New Keynesian literature.

Regarding the sectoral heterogeneity, we use 74 sectors. The number of sectors is dictated by the industry classification used to merge wage and price datasets as described in section 2.3. Sectors assume Calvo-style contracts for prices and wages within each sector, and the adjustment hazard rates across sectors might differ. Also, sectors have different weights. We use the official CPI weights for this matter. Weights and frequencies of adjustment are those reported in Table 2.2.

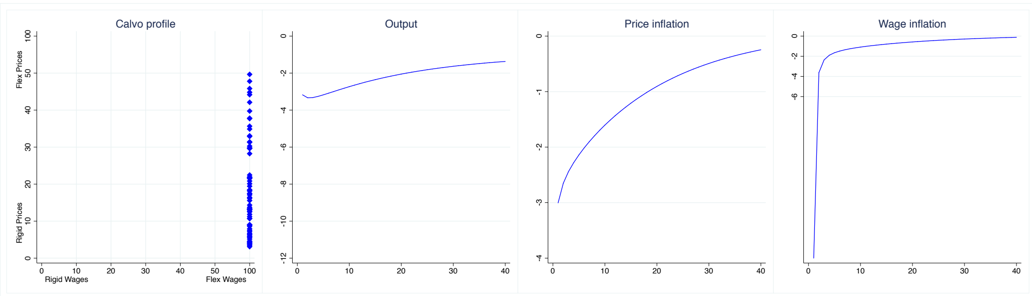
Figure 2.8: Multi-sector economy: Posted prices and wages (i)



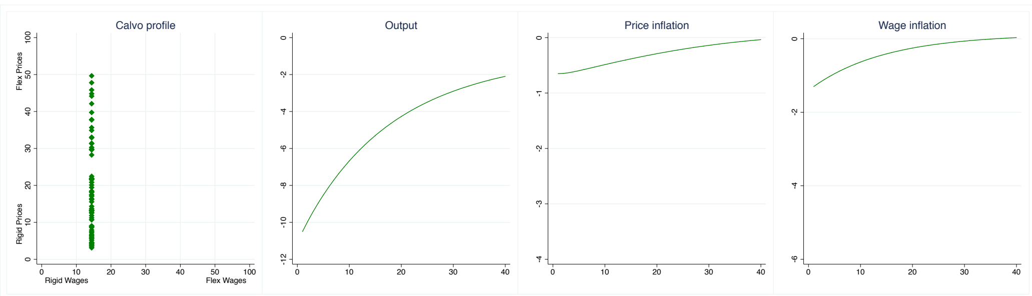
(a)



(b)



(c)



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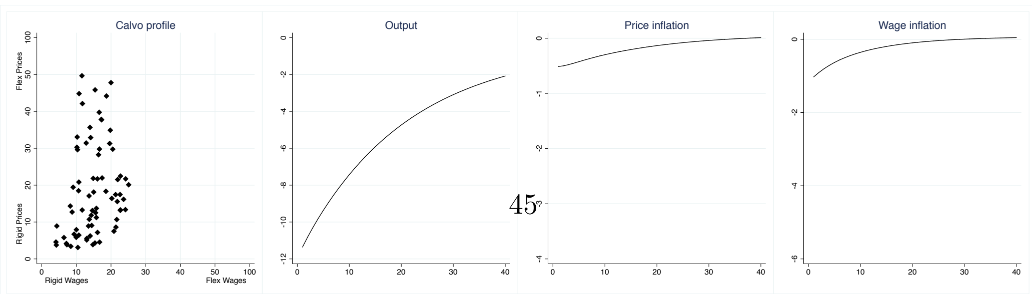
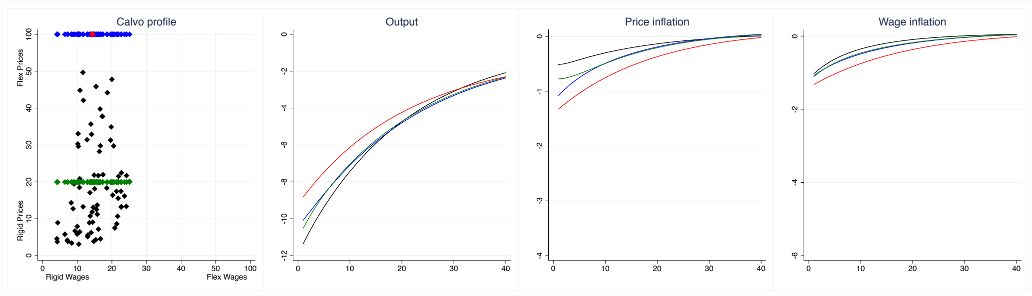


(e)

Figure 2.9: Multi-sector economy: Posted prices and wages (ii)



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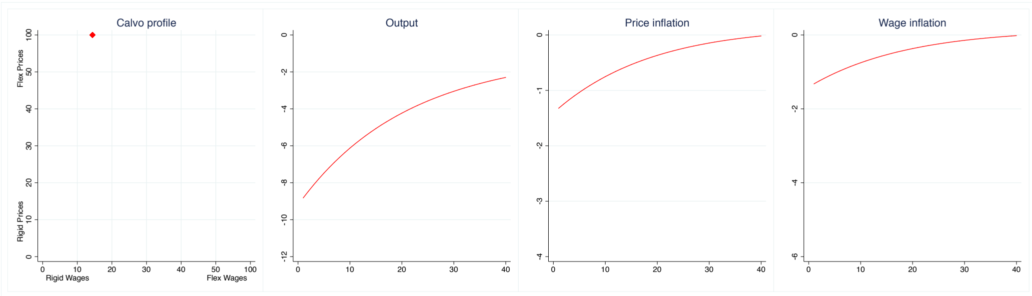
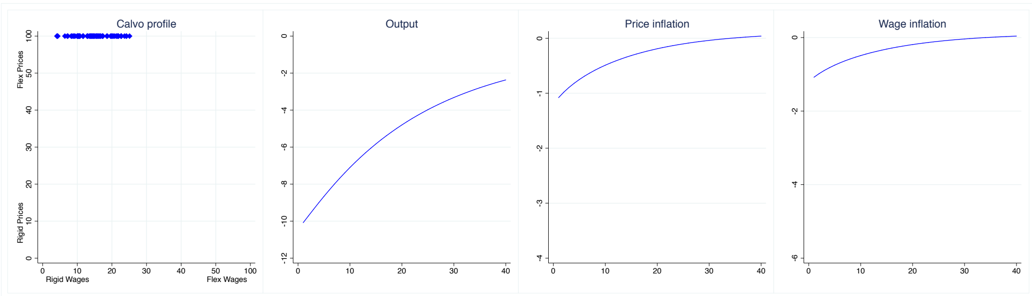
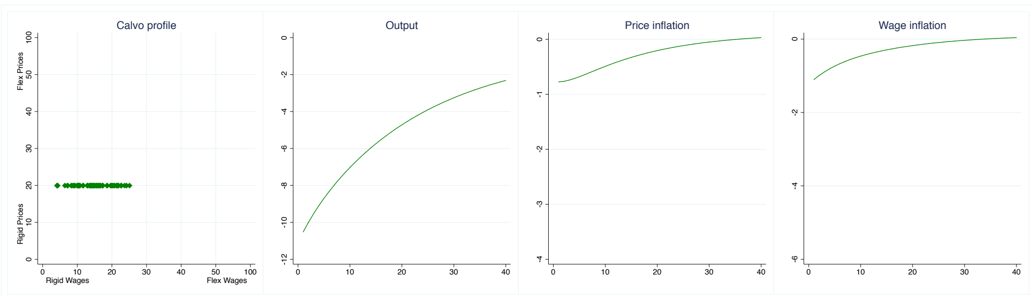


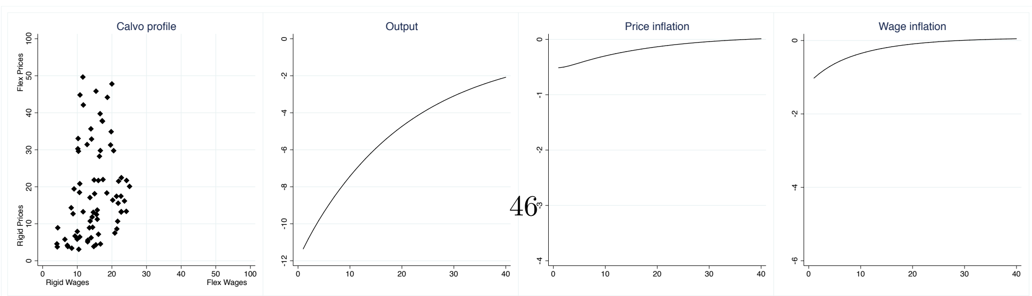
(b)



(c)

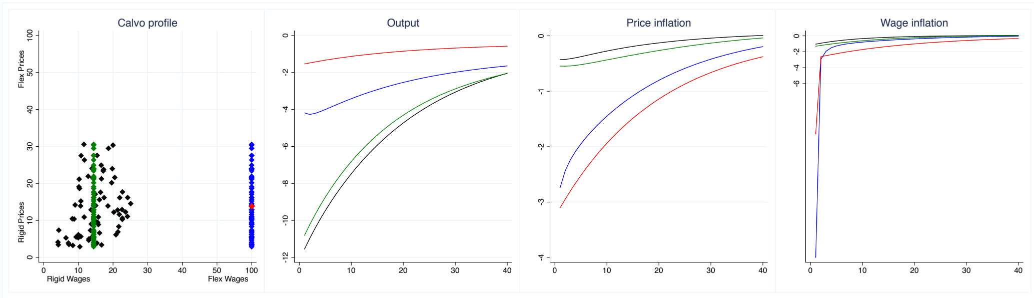


(d)

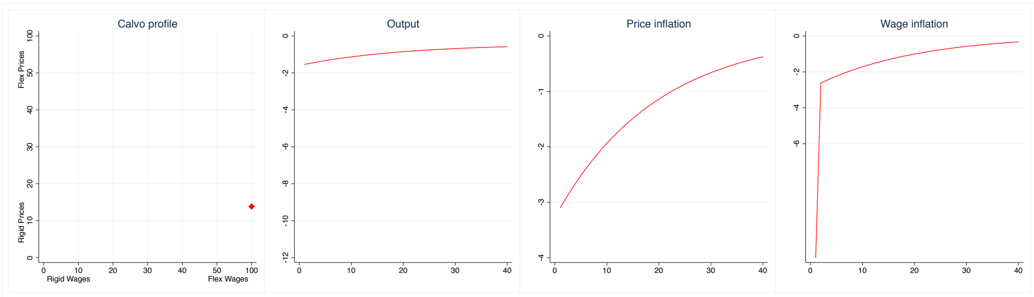


(e)

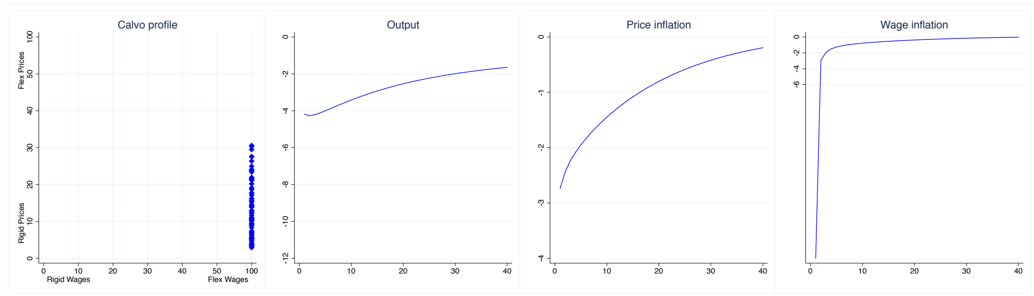
Figure 2.10: Multi-sector economy: Reference prices and wages



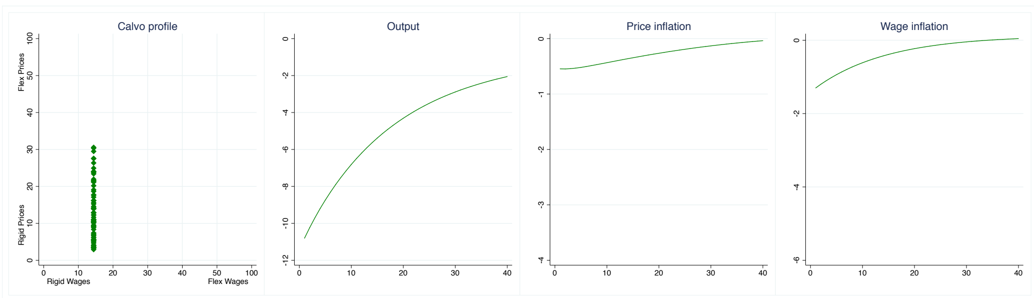
(a)



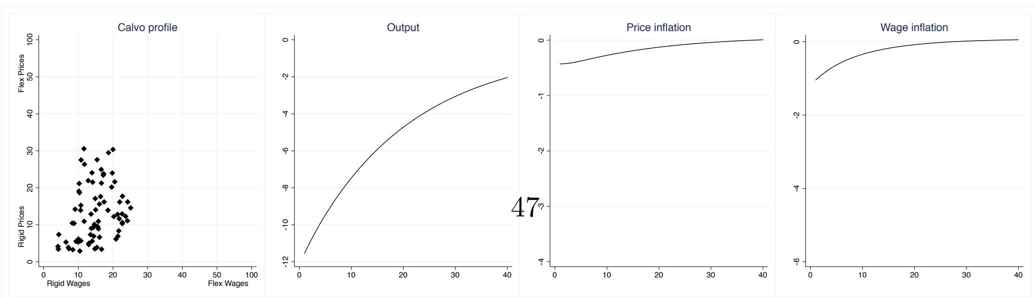
(b)



(c)



(d)



(e)

2.8.2 Analysis

Our primary goal is to study the implications of having the complete price-wage Calvo-distribution in a multi-sector economy. To that end, we use a number of different set of Calvo calibrations, or Calvo-profiles, to assess how aggregate dynamics of output, price and wage inflation change when we use each of them. Figures 2.8, 2.9 and 2.10 depict all the different calibrations in our study.

Before we describe our main results, it is important to add few remarks describing the structure of figures 2.8, 2.9 and 2.10 as they are crucial to understand our theoretical exercise.

First, focusing on the upper left graph of figure 2.8, we plot the different Calvo-profiles used in our different simulations. The vertical and horizontal axis of this graph represent the frequency of adjustment of posted prices and wages respectively. Each marker corresponds to one sector. Importantly, colours are used to differentiate across different Calvo-profiles, each of them is used in separate simulations. That is, the red marker on the right edge in the upper left graph implies that all 74 sectors share the same Calvo parameter for prices (denoted by its hight in the graph) and the same Calvo parameter for wages (fully flexible in this case). The simulation employing the red diamond can be seen as a single-sector economy with sticky prices and flexible wages. Blue dots correspond to a different calibration. Blue dots imply a multi-sector economy, each sector with a distinctive Calvo parameter for prices but all sectors having flexible wages. Similarly, green markers represent a different economy. The green economy is calibrated under heterogeneous price stickiness and homogeneous wage stickiness. Lastly, black dots denote a Calvo-profile under heterogeneous sticky prices and heterogeneous sticky wages simultaneously. Notice that the black distribution is complete price-wage Calvo-distribution as observed directly from our micro-datasets. Hence, it embeds the positive-related price and wage stickiness.

Second, the upper four graphs in figure 2.8, from left to right, depict the Calvo-profiles and impulse response functions of output, price inflation and wage inflation respectively. In that upper panel, the four lines in each of the impulse response functions corresponds, by color, to each of the four Calvo-profiles on the left as described in the previous paragraph. For example, the single red marker in the upper left graph (corresponding to the single-sector economy with sticky prices and flexible wages) generates the responses in red on the same panel 2.8a. Similarly, the set of blue markers in the Calvo-profile (heterogeneous sticky prices and flexible wages) are used to calculate the blue lines on the graphs to the right in the same panel.

Third, panel 2.8a in figure 2.8 plot the four different calibrations simultaneously for an easy comparison. In contrast, panels 2.8b, 2.8c, 2.8d and 2.8e plot separately each of the four Calvo calibrations being discussed so far. In other words, panel 2.8b depicts a single sector economy with sticky prices and flexible wages as in Galí [2015]; panel 2.8c shows results from a multi-sector economy with heterogeneous price stickiness and flexible wages as in Carvalho [2006]; panel 2.8d plots a multi-sector economy with heterogeneous price stickiness and homogeneous wage stickiness similar to Kara [2015]; and panel 2.8e graphs a multi-sector economy with the complete Calvo-distribution for prices and wages i.e. heterogeneous price stickiness and heterogeneous wage stickiness. In sum, panel 2.8a combines panels 2.8b, 2.8c, 2.8d and 2.8e.

Forth, figures 2.9 and 2.10 follow the same intuition. That is, the first upper left graph depicts different Calvo calibrations by colours; the colours of the impulse response functions come from the different Calvo profiles to the left; and the upper panels in figures 2.9 and 2.10 combine the remaining four panels below.

We now move on into describing our results. First, as noted by Carvalho [2006], a multi-sector economy with heterogeneous price stickiness generates greater real effects than a single sector economy, see red and blue lines in panel 2.8a. Also, Carvalho [2006] stressed the fact that a heterogeneous economy has a muted inflation response compared to a homogeneous economy. Not surprisingly, in these two economies we assume flexible wages and, hence, observe large wage swings.

Between these two economies, a single sector economy with sticky prices and flexible wages (red economy) and heterogeneous price rigidities with flexible wages (blue economy), we observe what the literature on heterogeneous nominal rigidities commonly refers as selection effects.[19] The inflation response in the blue economy has a very steep slope soon after the shock hits the economy. The response is mainly driven by sectors with higher frequency of adjustment. As periods pass by, the inflation response becomes flatter as it is dictated by sectors with lower frequency of adjustment.

[19]The term "selection effects" has been used in two different contexts that, although related, it is worth drawing a distinction. First, in the context of a single sector economy, the Calvo model is said to have no selection effects as adjusting-price firms are chosen randomly. In other words, new and old prices are equally likely to change. In contrast, the menu-cost framework is said to have strong selection effects as adjusting-price firms are those whose have deviated the most from their optimal price. See Carlsson [2017] or Nakamura and Steinsson [2010]. Second, a multi-sector economy with heterogeneous frequency of price adjustments is said to have selection effects since the composition of firms resetting prices is not "purely" random. As Kara [2015] explains, although there is still a constant fraction of firms resetting prices in the economy, firms resetting prices are mostly chosen from sectors with higher frequency of adjustments as dictated by the sectoral distribution/structure assumed in the economy.

Also, it is worth noticing the multi-sector economy with heterogeneous price rigidities and flexible wages (blue economy) generates a hump-shaped response in output after a monetary policy shock. As Kara and Park [2017] notice, empirical studies show that monetary policy shocks generates hump-shaped response in output but the New Keynesian literature has found it hard to emulate such response. Kara and Park [2017] show analytically that accounting for heterogeneity in price rigidities can generate a hump-shaped response in output after a monetary policy shock. Moreover, Kara and Park [2017] find that the baseline Calvo model cannot generate the hump. Results from our red and blue economies are in line with Kara and Park [2017] results.

Second, the introduction of sticky wages generates greater and more persistent output effects, and muted price and wage inflation response. See green line in panel 2.8a. Intuitively, after the interest rate shock, the adjustment process requires lower prices due to the fall in output demand. Although in this case all sectors share the same Calvo-wage parameter, wages are affected by the overall price level, output, sectoral wage and, importantly, sectoral output. At the same time, sectoral output is driven by the sectoral relative price, which in turn is heterogeneous due to the heterogeneous Calvo-prices. Therefore, the introduction of homogeneous Calvo-wages serves as a multiplier of results drawn from the price heterogeneity previously introduced (blue line).

Third, the use of the Calvo-pairs presented in our empirical section and embedding the positive correlation between prices and wages is depicted in black in figure 2.8a. Comparing black and green lines from figure 2.8a the differences are small for output, price and wage inflation. The intuition carries on from the previous paragraph, the only difference is that Calvo-wages are heterogeneous in this case, and hence, the marginal cost faced by firms in different sectors vary as well. However, the marginal cost already varied at different rates with price heterogeneity. Therefore, the introduction of both price and wage heterogeneity only has limited impact compared to the case with heterogeneous prices and sticky wages.

Alternatively, we can analyse the multi sector economy starting from the flexible prices but sticky wages case. These cases are depicted in figure 2.9. The starting point is having a multi-sector economy with common Calvo-wage parameter across sector and flexible prices, shown in panel 2.9b. Then, likewise with the price heterogeneity analysis in figure 2.8, we proceed analysing the role of heterogeneous Calvo-wages and flexible prices (2.9c); heterogeneous Calvo-wages and sticky prices (2.9d); and a multi-sector economy with the complete price and wage Calvo-distribution (2.9e).

Although wage heterogeneity also produces greater real effects after a monetary policy shock, the difference with respect to a homogeneous economy is less evident than what it's observed in the heterogeneous pricing case. For instance, the homogeneous economy depicted in panel 2.9b causes about 25% less output effects on impact than the multi-sector economy shown in panel 2.9c. In contrast, pricing heterogeneity generates more than 100% (see figures 2.8b and 2.8c). Also, adding homogeneous sticky prices increases the real effects only marginally. See panel 2.9d. Finally, the model with the complete Calvo-distribution, shown in panel 2.9e, is the one with greater real effects among all these different cases.

The key element on why price (wage) heterogeneity matters more (less) when wages (prices) are flexible or not, figures 2.8d and 2.8e (figures 2.9c and 2.9d), comes from the marginal costs face by firms. In the first case, by adding sticky wages, the marginal cost no longer is automatically adjusted, hence nominal wage rigidities act on top of price heterogeneity, and therefore greater real effects. See blue and green lines in figure 2.8. In contrast, when price stickiness is combined with wage heterogeneity, firms freely or not to reset prices might not do so because of the heterogeneous marginal cost stemming from the Calvo-wage distribution. See blue and green line from figure 2.9.

We also provide evidence using reference prices. This Calvo-distribution is depicted in figure 2.10. Similarly to our conclusions using posted prices, heterogeneous pricing with flexible wages generates more real effects than a single sector economy; adding sticky wages to a heterogeneous pricing economy produces more real effects than before; and the introduction of heterogeneous wages to heterogeneous pricing only affects output responses marginally. Price inflation responses follow exactly the opposite order- highest inflation rates are observed in the single sector economy and the most muted inflation is achieved under the complete Calvo-distribution. By using the Calvo-distribution of reference prices, the model generates more persistent effects than that with posted prices. This is not surprising since reference prices are more rigid than posted prices.

One result stands out from our analysis. Introducing heterogeneity on both nominal dimensions, prices and wages, by using the complete Calvo-distribution does not generate much more real effects than an economy with heterogeneous prices (wages) and homogeneous wage-setting (price-setting) case. This result holds regardless one assumes a positive correlation (panel 2.8e) or no correlation (panels 2.8d and 2.9d) across industries.

Fitting a multi-sector economy complicates a DSGE model even when considering a simple production function. Hence, an obvious question is, what is the parametrisation needed in a single sector economy to generate the same real effects as a multi-sector model using the complete Calvo-distribution.

Carvalho [2006] follows a similar strategy with the caveat of using flexible wages. In his research, Carvalho [2006] finds that, instead of using the weighted mean or median as the Calvo calibration, one should use one third of the mean to generate the same output effects.

Our strategy for finding the best Calvo calibration in an homogeneous economy is as follows. First, we calculate the weighted mean in our Calvo-distribution. See orange diamond in figure 2.11a. Second, we retrieve the coefficient found in our IV estimation from table 2.3. Third, taking the mean as the starting point, we draw Calvo-pairs (prices, wages) fitting the IV slope. These Calvo-pairs are depicted as navy blue dots in figure 2.11a. Notice that, in order to find the optimal Calvo calibration under sticky prices and wages, one has to search in a $\mathbb{R}^2$ space. In contrast, Carvalho [2006] moves along $\mathbb{R}$ dimension as exemplified in figure 2.11b due to flexible wages in his model. We believe that moving along the IV slope is the best approach given the positive correlation between the frequency of price and wage adjustments across industries.

We calculate the Mean Square Error (MSE) between output and inflation responses under the complete Calvo distribution and the single sector economy. Then, we retrieve the Calvo-pair producing the lowest MSE.

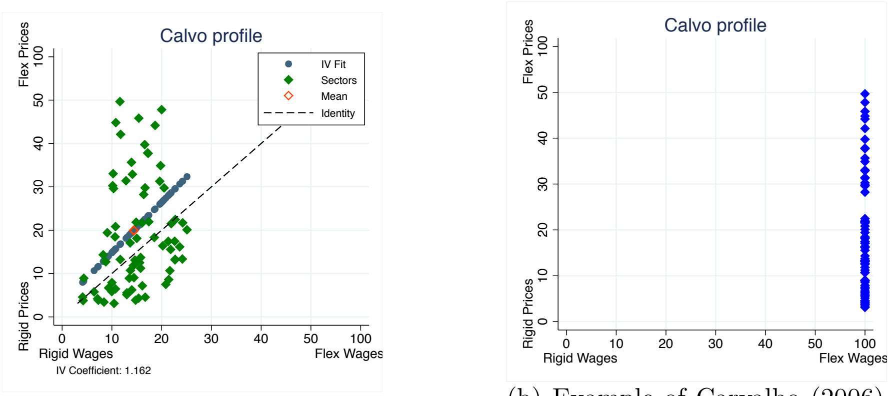
Table 2.9 shows the Calvo pair that minimises the MSE of output and price inflation responses with respect to the multi-sector economy. We find that the Calvo-price parameter is about 3/4 of the mean. This result contrasts substantially with Carvalho's 1/3 factor. The difference relies on the fact that sticky wages in our model reinforces price rigidities. Similarly, given the IV coefficient, the Calvo-wage parameter is around 3/4 of the mean.

Finally, we plot the impulse response functions for the 3 models in figure 2.12: in orange the single sector economy calibrated with Calvo means for both prices and wages; in green the multi-sector economy with the complete Calvo distribution; and in navy blue the single sector economy that best replicates the multi-sector economy.

Table 2.9: Best fit by single-sector economy

	Mean		Best fit	
	Frequency (%)	Duration (Months)	Frequency (%)	Duration (Months)
Prices	19.94	4.50	15.01	6.15
Wages	14.42	6.42	10.17	9.32

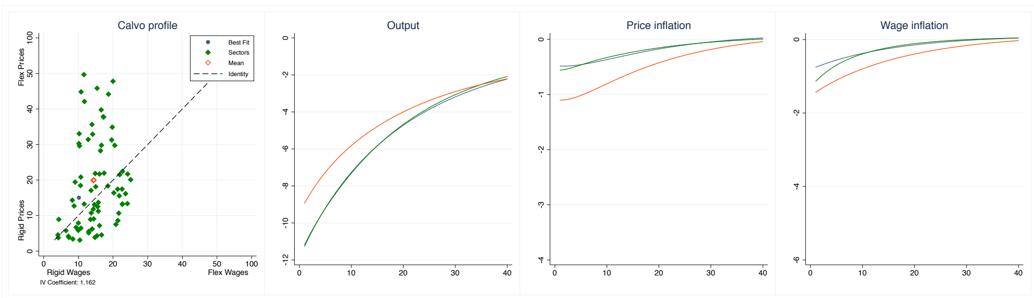
Figure 2.11: Calvo-distribution



(a) Calvo distribution in $\mathbb{R}^2$

(b) Example of Carvalho (2006) calibration in $\mathbb{R}$

Figure 2.12: Best fit by a single sector economy



2.9 Conclusions

Nominal frictions are key elements in New Keynesian models studying the effects of monetary policy. To that end, measures of price and wage stickiness are embedded in these models. A standard simplification in NK literature is that price and wage stickiness are set independently one from the other, despite their obvious correlation through the cost function.

By merging large price and wage micro datasets at industry level, we contribute to the nominal rigidities literature by documenting that (i) the frequency of price adjustments is positively correlated with the frequency of wage updates; (ii) reference prices are stickier than wages but wages are stickier than posted prices; (iii) frequency of adjustments is heterogeneous across industries for both prices and wages; (iv) absolute size of price adjustments is heterogeneous for prices but not for wages; and (v) frequency and size of adjustments are negatively correlated, not only for prices but for wages as well. To the authors' knowledge, this is the first study merging quantitative price and wage data at such large scale- millions of price and wage quotas.

Moreover, we analyse what are the implications of our empirical findings (i), (ii) and (iii) in a multi-sector economy using the time-dependent price- and wage-setting framework proposed by Calvo (1983). Since empirical findings (iv) and (v) would require the use of a state-dependent framework, we leave the implications of these findings in an otherwise standard NK model for future research.

Using our multi-Calvo economy, we find that a multi-sector economy under heterogeneous Calvo prices (wages) and flexible wages (prices) generates greater real effects than a multi-sector economy under homogenous Calvo prices (wages) and flexible wages (prices). Furthermore, if we calibre our multi-sector economy with heterogeneous Calvo prices (wages) and homogeneous Calvo wages (prices), we obtain greater real effects than before. Finally, by using the complete Calvo-distribution, i.e. heterogeneous Calvo prices and heterogeneous Calvo wages, the gains of real effects are only marginal. Thus, introducing simultaneously price and wage heterogeneity has limited impact relative to the heterogeneous price (wage) and homogeneous wage (price) case.

Hence, the positive correlation [finding (i)] and heterogeneity in both frequencies of adjustments [finding (iii)] seem not to play a major role in generating contrasting output persistence compared to other specifications. At the same time, since reference prices are stickier than posted prices [finding (ii)] we find greater response of output and more muted inflation response. Though, the dynamics of the model stay fairly similar.

Adding wage and price heterogeneity complicates DSGE models, which are already quite complicated. Indeed, the main criticism of existing macro models is their complexity. Hence, we estimate that in the presence of both sticky wages and prices, a homogeneous (single-sector) economy calibrated with 3/4 of the weighted mean of frequency of price and wage adjustments generates the same real effects as the heterogeneous economy.

Taken together, these results confirm previous findings on the heterogeneity of nominal rigidities and its implications for aggregate dynamics in workhorse models. The high degree of heterogeneity in wage and price setting practices is present across firms, products, and types of workers, etc. Thus, future macroeconomic research should transit from studying homogenous economies with a representative firm to models incorporating heterogeneous wage- and price-setters. As suggested by Dixon and Kara [2010] and Kara and Park [2017], this approach is consistent with evidence found in microdata; and it does not require the use of ad-hoc mechanisms (e.g. indexation or habit formation) to reconcile macroeconomic models' impulse response functions with empirical VARs results.

A natural progression of this work is to analyse findings (iv) and (v) by endogenising the joint price and wage setting decision via state-dependent frameworks. Also, our study is limited to industry linked microdata. Firm level data, for instance, would shed further light on the mechanisms driving the frequencies of price and wage adjustments.

The main challenge for this area in macro research remains as how to incorporate the great variety of wage and price setting practices in a way that is tractable for policy analysis.

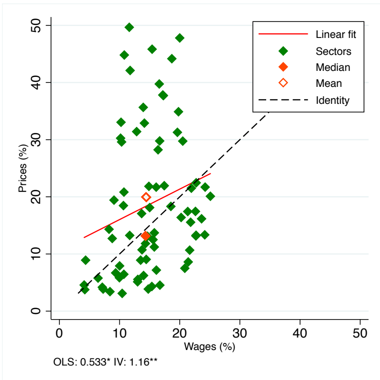
2.10 Appendix

Table 2.10: Appendix: Aggregate frequency of adjustment

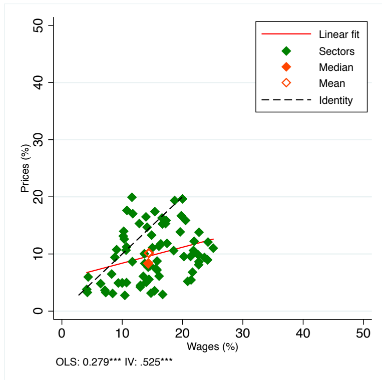
	Median		Mean	
	Frequency (%)	Implied Duration (Months)	Frequency (%)	Implied Duration (Months)
Posted Prices	13.16	7.09	19.94	4.50
Reference P (3m)	10.39	9.12	13.84	6.71
Reference P (6m)	8.35	11.47	10.15	9.34
Wages	14.31	6.48	14.42	6.42
Wages (no caps)	15.41	5.97	15.12	6.10
Earnings	18.81	4.80	17.55	5.18

Calvo parameters around the globe (monthly equivalent):
All prices: US 19.3%, France 19%;
Prices excluding sales: US 8.9%, UK 14%;
Wages: US 9.9%, France 14.7%

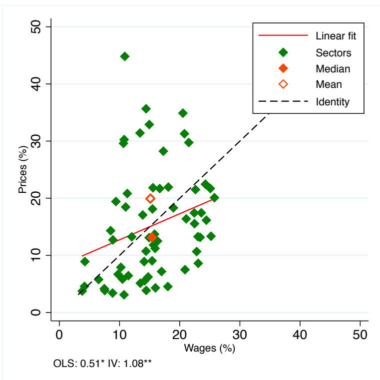
Figure 2.13: Appendix: Frequency of adjustment



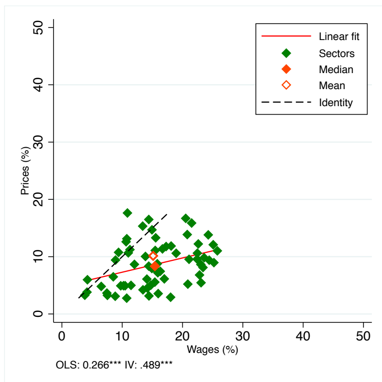
(a) Posted Prices and Wages



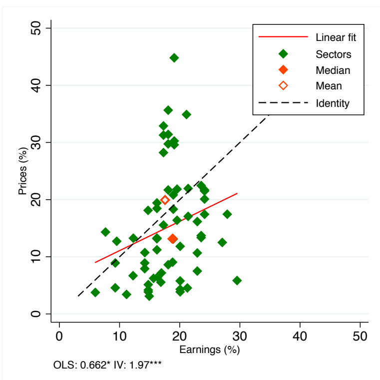
(b) Reference Prices (6m) and Wages



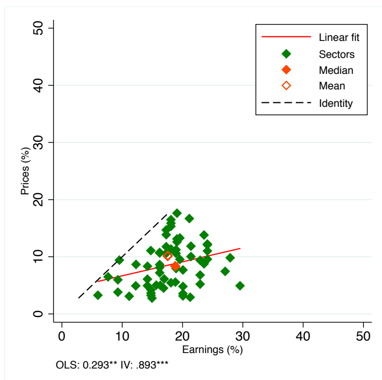
(c) Posted Prices and Wages wo caps



(d) Reference Prices (6m) and Wages wo caps

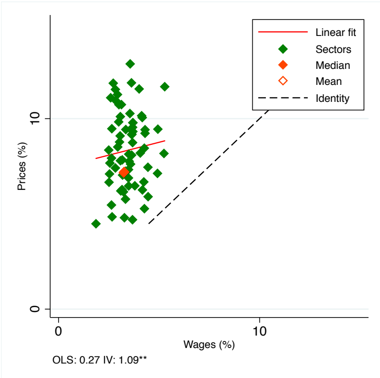


(e) Posted Prices and Earnings

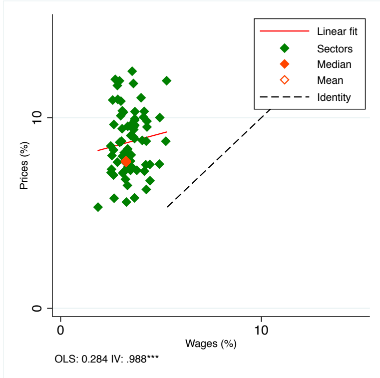


(f) Reference Prices (6m) and Earnings

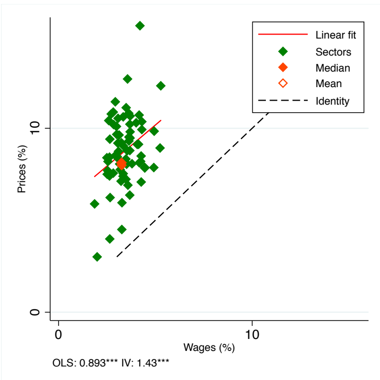
Figure 2.14: Appendix: Absolute size of adjustments



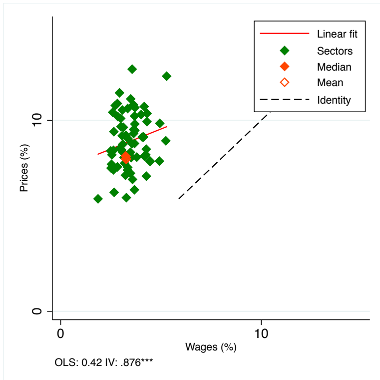
(a) Posted Prices and Wages (no outliers)



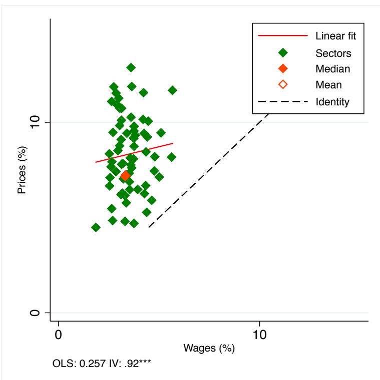
(b) Reference Prices and Wages (no outliers)



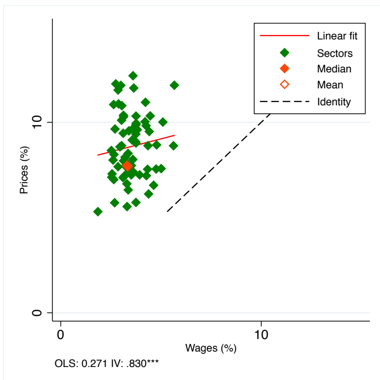
(c) Reference Prices (6m) and Wages



(d) Reference Prices (6m) and Wages (no outliers)

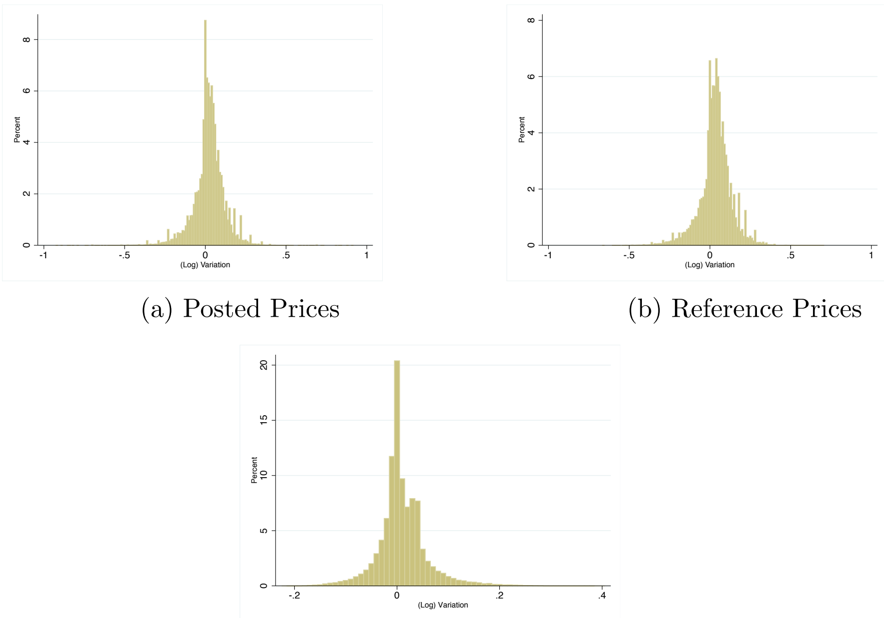


(e) Posted Prices and Wages (no MW)



(f) Reference Prices and Wages (no MW)

Figure 2.15: Appendix: Distribution of non-zero changes



(a) Posted Prices

(b) Reference Prices

(c) Wages

Table 2.11: Appendix: Sectoral frequency of adjustment

	Frequency of Adjustment				
	Weight (%)	Ref Prices (%)	Ref Prices (6m) (%)	Wages (%)	Wages wo MW (%)
Prepared meals	0.64	24.92	16.30	16.60	17.35
Coffee	0.23	21.15	13.97	10.25	10.71
Sugar ind	0.31	29.48	19.36	18.69	19.19
Livestock and poultry	7.23	27.58	17.41	15.41	15.83
Dairy products	4.52	23.39	15.32	17.19	18.02
Seafood packaging	0.26	26.34	17.04	11.76	12.08
Rice	0.23	30.55	19.93	11.62	12.29
Chocolate and others	0.16	23.79	15.87	17.29	18.11
Animal food	0.17	21.25	15.26	16.67	17.12
Fats and oils	0.48	30.35	19.64	20.00	20.79
Food (others)	1.42	18.66	12.60	10.34	10.65
Grain and seed milling	0.39	27.51	17.62	10.79	10.87
Bakery and tortilla	3.93	19.08	13.13	10.17	10.76
Tequila industry	1.11	21.51	14.69	14.13	14.94
Beer industry	2.21	20.17	13.86	19.62	20.79
Soft drinks industry	2.72	17.62	11.77	16.40	17.28
Tobacco industry	0.90	11.62	10.61	21.81	22.46
Other textile products	0.43	9.51	7.44	15.57	16.31
Cut and sew apparel	5.29	6.92	5.56	14.43	15.41
Footwear	2.24	7.34	6.09	13.50	14.09
Other leather products	0.13	6.15	4.93	10.01	10.22
Wooden products (excl furniture)	0.18	14.19	10.75	9.08	9.40
Furniture	1.40	15.24	11.23	10.73	11.29
Paper products	3.15	23.98	16.69	19.79	20.53
Newspaper and book printing	2.09	5.59	5.03	14.00	14.75
Fertilizers and pesticides	0.13	21.93	15.33	12.84	13.40
Pharmaceutical products	1.78	21.61	15.87	20.50	21.51
Soaps and cleaners	4.43	24.05	16.49	13.94	14.41
Lotion and perfumes	1.41	15.59	11.36	16.09	16.68
Candles and others	0.05	13.91	10.67	10.64	11.01
Chemical products (others)	0.06	6.91	5.45	21.42	23.08
Petroleum products (others)	0.22	14.04	11.09	15.01	15.48
Rubber products	0.20	17.08	13.30	14.88	15.55
Plastic products	0.06	12.22	9.54	20.23	21.08
Glass and glass products	0.13	12.94	9.82	22.62	23.58
Tools and utensils	0.28	16.17	11.86	17.43	18.11
Tools and utensils (others)	0.12	12.89	10.04	13.67	13.85
Computer equipment	0.34	8.35	6.81	21.66	22.82
Audio and video equipment	0.90	12.27	9.39	23.63	24.43
Magnetic and optical media	0.65	6.14	5.21	20.84	20.88
Household electrical app (others)	0.28	14.56	11.02	25.10	25.77
Batteries	0.06	16.15	12.22	21.93	22.62
Lighting accessories	0.07	12.81	9.57	21.33	22.43
Household electrical appliances	0.61	16.18	12.09	24.23	25.09
Motor vehicle parts	0.09	11.08	8.96	24.16	25.21
Other transport. equipment	0.03	10.92	8.76	15.78	15.82
Automobiles	4.98	17.71	13.81	22.74	24.27
Ophthalmic goods mfg	0.32	10.29	8.11	22.69	23.40
Photography equipment	0.15	10.11	7.94	14.63	14.92
Toys	0.66	8.90	7.20	15.77	15.91
Stationary	0.20	10.60	8.64	22.71	23.04
Dental offices	0.10	3.52	3.25	7.27	7.55
Other manufacturings	0.32	13.92	10.59	18.53	18.95
Water supply	1.12	10.91	8.66	11.69	12.03
Passenger transportation	6.54	5.53	4.92	9.35	9.76
Accounting services	0.27	3.39	2.92	16.70	18.03
Self-service and takeaways rest	10.31	9.28	7.69	14.31	15.64
Restaurants full service	0.63	5.30	4.81	6.43	6.53
Film and video industry	0.74	6.62	6.13	16.12	16.98
Nightclubs and similars	0.73	3.50	3.15	14.77	14.44
Recreational services	1.06	3.88	3.55	15.37	15.97
Automobile maintenance	0.73	5.66	4.99	10.72	11.46
Household goods repair	0.20	7.37	5.98	4.36	4.24
Beauty salons and clinics	0.83	4.14	3.81	4.12	4.17
Laundries and dry-cleaning	0.49	4.99	4.52	13.03	14.16
Real estate services	0.91	3.26	3.09	8.41	8.84
Funeral services	0.19	5.33	4.93	9.98	10.49
Domestic personnel	2.25	3.42	3.27	4.23	3.80
Parking vehicles services	0.05	2.91	2.76	10.44	10.75
Education services	7.56	9.04	8.35	13.73	14.40
Hospitalization services	2.96	3.91	3.65	7.13	7.46
Medical diagnostic	0.88	4.66	4.22	13.00	13.44
Nurseries	0.29	10.39	9.41	8.78	8.89
Governmental fees	0.82	10.44	6.49	8.26	8.52

Table 2.12: Appendix: IV: Frequency of posted price and wage adjustments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	2SLS	IV	IV	IV
VARIABLES	Posted P	Posted P	Posted P	Posted P	Posted P	Posted P	Posted P
Freq Wage Adj	0.533**	0.964***	3.375***	1.348***	0.779**	0.978**	1.162**
	(0.224)	(0.277)	(1.050)	(0.271)	(0.334)	(0.392)	(0.463)
Labor Share					-0.246***		-0.374***
					(0.058)		(0.070)
Import Intensity						-0.005	-0.186***
						(0.071)	(0.064)
Constant	0.107***	0.042	-0.319**	-0.015	0.123**	0.043	0.178**
	(0.038)	(0.043)	(0.151)	(0.039)	(0.061)	(0.041)	(0.077)
Observations	74	74	74	74	74	74	74
R-squared	0.048	0.017	0.121	0.598	0.191	0.015	0.202
IV		MW Sh	Labor Share	MW Sh	MW Sh	MW Sh	MW Sh
IV2		.	.	Labor Share	.	.	.
Adj R2		0.534	0.122	0.598	0.598	0.616	0.622
Robust F		48.939	9.471	56.526	67.257	32.391	41.558
Min Eig		84.554	11.103	55.333	86.393	65.909	68.563

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.13: Appendix: IV: Frequency of reference price and wage adjustments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	OLS	IV	IV	2SLS	IV	IV	IV
VARIABLES	Ref P	Ref P	Ref P	Ref P	Ref P	Ref P	Ref P
Freq Wage Adj	0.386***	0.675***	2.123***	0.906***	0.564***	0.673***	0.781***
	(0.134)	(0.170)	(0.653)	(0.168)	(0.201)	(0.236)	(0.275)
Labor Share					-0.148***		-0.220***
					(0.035)		(0.041)
Import Intensity						0.001	-0.105***
						(0.042)	(0.038)
Constant	0.075***	0.031	-0.186**	-0.003	0.080**	0.031	0.111**
	(0.022)	(0.026)	(0.094)	(0.024)	(0.036)	(0.025)	(0.045)
Observations	74	74	74	74	74	74	74
R-squared	0.070	0.031	0.142	0.579	0.208	0.031	0.208
IV		MW Sh	Labor Share	MW Sh	MW Sh	MW Sh	MW Sh
IV2		.	.	Labor Share	.	.	.
Adj R2		0.534	0.122	0.598	0.598	0.616	0.622
Robust F		48.939	9.471	56.526	67.257	32.391	41.558
Min Eig		84.554	11.103	55.333	86.393	65.909	68.563

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Chapter 3

Heterogeneous Exchange Rate Pass-Through: Micro-Level Evidence From Mexico

3.1 Introduction

An important challenge for policy makers is to understand how external factors affect domestic economic activity. Specifically, nowadays globally integrated economies are concerned by the domestic implications of exchange rate movements. Inflation and business cycles, among others economic phenomena, are reflected and transmitted via exchange rate fluctuations.

From a domestic point of view, exchange rate volatility induces instability and uncertainty to firms, consumers, and policy makers in their economic decisions. Not surprisingly, one transmission mechanism of exchange rate movements into the economy is via pricing behaviour. Exchange-rate effects on prices might create domestic disruptions and offset international competitiveness. In other words, a price increase of imported inputs and/or final goods from an exchange rate depreciation of domestic currency can potentially spill over to other sectors of the economy, raising overall domestic production costs and leading to an inflationary spiral. Hence, understanding the phenomena of gradual adjustment of prices due to exchange rate shocks is essential in the design of monetary and exchange rate policies.

The literature commonly refers as Exchange Rate Pass-Through (ERPT) as the percent change in local currency prices resulting from a one percent change in the bilateral exchange rate. If the effect of a domestic depreciation is fully reflected in domestic prices, then pass-through is said to be full or complete. If only a portion of the depreciation is reflected in prices, then pass-through is described as partial or incomplete.

This paper contributes to the growing literature using micro data to further understand ERPT and its likely drivers in a small open economy. First, using a micro-dataset of Mexican consumer prices, this essay critically examines if there are heterogeneous levels of ERPT within the country. The novel dataset allows pass-through estimation in two dimensions: across various urban regions and throughout different types of goods and services. Second, we match our micro-data findings to regional and industry macro data. Then, we study whether contrasting levels of pass-through can be associated to regional and/or industry characteristics. Regional characteristics such as distribution costs, market density, demand conditions, economic development are examined, as well as industry features like import intensity, price dispersion and expenditure share are addressed in our analysis.

Our results can be summarised as follow. We find that there are heterogeneous ERPT rates within the Mexican territory. On the one side, heterogeneity is present at the regional dimension. That is, even within industries, pass-through estimates are different across regions. Moreover, we perform a bottom-up exercise to obtain a single (aggregate) regional pass-through. This approach also confirms uneven pass-through responses across regions. On the other side, we find pass-through heterogeneity across industries. In other words, we corroborate that different types of goods and services exhibit different pass-through elasticities.

The relation between prices and exchange rates is one of the classic topics analysed in international macroeconomics. One strand in the literature studies the responsiveness of prices at different stages in the production process (e.g. import, wholesale and retail prices). For example, Bacchetta and van Wincoop [2003] analyse the degree of pass-through to final (consumer) prices and intermediate (import and export) prices. Other strands in the literature examine the influence of exchange rates on prices using highly desegregated datasets. As documented by Nakamura and Steinsson [2012] and Gopinath and Rigobon [2008], stickiness observed in price indexes masks substantial amount of heterogeneous behaviour of prices at a disaggregated level. Another strand in the literature has recently focused, instead of addressing whether pass-through is complete or incomplete, in whether pass-through is endogenous to the domestic economy. More generally, whether ERPT is a micro or macro phenomenon as argued by Fue [2012] and Campa and Goldberg [2005].

The presence of heterogeneous price responses to exchange rate shocks is not trivial for policy-makers. This is particularly relevant in inflation targeting regimes, where the monetary authority has a single instrument to conduct monetary policy.

Consider the following example. On the one hand, if ERPT was homogeneous across regions, the central bank can take proper actions to control aggregate inflation steaming from exchange rate shocks. By controlling aggregate inflation, the interest rate adjustment required to maintain the inflation target across regions would be the same.

On the other hand, if ERPT is heterogeneous across regional economies, a single monetary policy can have asymmetric effects in the different regions. In other words, regional economies displaying higher pass-through elasticities would require a more aggressive policy respond to maintain the inflation target than lower pass-through regions. If the central bank sets its policy to control aggregate inflation, the interest rate adjustment would not be enough to meet the inflation target in high pass-through regions; and low pass-through regions would suffer from a tighter than needed monetary policy.

Thus, as the monetary authority has a single instrument to conduct monetary policy, its actions can have asymmetric effects across different regions in the presence of heterogeneous ERPT. Campa and Mínguez [2006] rise a similar point regarding the monetary union in the Euro-area and the concern that external factors affect differently its member states. Hence, comprehending regional pass-through levels provides insights to transmission mechanisms of exchange rate fluctuations in the domestic economy.

Furthermore, understanding which industries react promptly to cost shocks, due to currency depreciations, assists policy makers in taking decisions. If ERPT varies because of industry characteristics, authorities could intervene in the market structure (e.g. regulations on compeition) to alleviate or understand distortions in the CPI stemming from exchange rate fluctuations.

Therefore, recognising heterogeneous responses across regions and industries is of particular interest for policy makers.

Although past consensus led by Taylor [2000] suggest low and declining ERPT in price indices, debate continues regarding evidence of high and persistent pass-through at the micro level as shown by Gopinath et al. [2010]. Most studies in ERPT have focussed on cross-country or particular industries. However, the existing literature fails to document if pass-through is uniform across the country, and if not, why would heterogeneous rates of pass-through prevail in the domestic economy. The novel micro-dataset used in this paper explores the possibility that heterogeneous ERPT rates prevail in different Mexican regions and examines if contrasting levels of ERPT are associated with local- and/or industry-specific characteristics. To the author's knowledge, no research studies whether the degree of ERPT to consumer prices varies across regions and/or products within a country and its determinants.

In what follows, a micro-dataset compiled by Banco de Mexico (Central Bank of Mexico), as well as regional and national accounts statistics, are exploited to shed light on the issues previously mentioned. The micro dataset reports more than 85,000 price trajectories at the retail level, collected from June 2002 to December 2010 in 46 urban areas in Mexico.

The regional and product-categories information in the dataset allows the estimation of subcomponents behind the aggregate pass-through statistic widely studied. That is, overall pass-through is decomposed into regional and product-categories pass-through rates. This study employs an aggregate pass-through regression widely used in microdata literature (e.g. Nakamura and Steinsson [2012] and Goldberg and Campa [2010]). The approach permits estimating the cumulative responses of monthly price variations (from an individual product in a particular region and category) to a change in the exchange rate for different time horizons.

Moreover, this paper investigates the potential drivers of the uneven responses across industries and regions. It explores macro and micro factors suggested in influential cross-country and industry-specific studies. Among others, transportation costs, regional economic development, market power, local demand conditions, pricing volatility and import intensity are critically assed as likely determinants of heterogenous pass-through within the country.

The rest of the paper is organised as follows. Section 3.2 gives a brief review of recent research findings. Section 3.3 provides details about the micro dataset. The econometric methodology for estimating ERPT rates is described in section 3.4. Section 3.5 outlines ERPT determinants. Section 3.6 analyses the empirical results. Finally, section 3.7 concludes.

3.2 Empirical evidence

In this section we review empirical and theoretical work that sheds light on retail price responses to exchange rates. The main focus is on regional and industry heterogeneity, as well as the likely determinants shaping price responses.

Our research fits into four main strands of exchange-rate pass-through literature. First, we begin by describing results from studies analysing final good's (retail) prices. There is a relatively small body of literature analysing retail prices compared to research on producer (wholesale) or border (at the dock) prices. Second, we summarise recent studies using microdata, which contrast with the original pass-through literature based on price indices. Third, we review results from cross-country and cross-industry analysis. Since there are no studies analysing within country responses to the author's knowledge, we provide a quick glance of cross-country evidence. Forth, we recapitulate on the mechanisms generating incomplete pass-through.

Research into ERPT has analysed price responses at different stages in the production line, from import prices, wholesale prices and final prices. Although ERPT to import and wholesale prices is informative for understanding price formation, ERPT to consumer prices is vital for conducting monetary policy in inflation-targeting economies as argued by Gagnon and Ihrig.

Perhaps the most serious disadvantage of studies scrutinising at the dock prices is that they do not incorporate local costs, which are critical determinants of final prices. In fact, Burstein et al. [2003] and Goldberg and Campa [2010] explore this hypothesis and argue that a large non-tradable component could significantly insulate consumer prices from exchange rate movements. For instance, the distribution margins of household consumption goods are between 30% and 50% of purchases prices across a sample of 21 OECD countries according to Goldberg and Campa [2010]. Similarly, Berger et al. [2012], using more granular US data, report that distribution margins constitute between 50% and 70% of final good prices in some manufacturing industries. Thus, Goldberg and Campa [2010] stress that CPI sensitivity to exchange rate fluctuations can be explained not only by costs arising from imported inputs and imported final goods but also by non-tradable goods and domestically produced goods or services.

Moreover, theoretical work by Dev [2010] and Corsetti et al. [2005] provide an alternative explanation on why pass-through to wholesale and retail prices might differ. Their argument is that, in addition to the local-value added components in final prices, retail prices may also exhibit greater menu-costs.

Our analysis centres in consumer prices. Hence, as previously mentioned, the transmission of exchange rate movements is through imported final goods, and imports embedded as inputs in domestic production of non-trable and tradable goods. Though, we would expect our ERPT estimates to be lower than those found by the import or wholesale prices literature.

Regarding the type of data employed in this research, we use highly disaggregated consumer price microdata. However, the ERPT literature has been a long tradition of exploiting aggregate price indices.[1] The use of aggregate data may reflect prices changing every period and makes it difficult to identify the role of local costs. Furthermore, Goldberg and Hellerstein [2013] maintain that by using price indices it is difficult to accurately assess the role of non-traded services or markup adjustments in price setting, and therefore explaining incomplete pass-through. This contrasts with micro-data evidence documented by Bils and Klenow [2004] suggesting retail prices commonly remain fixed for more than one period.

However, in recent years the availability of highly disaggregated data has allowed researchers to shed new light understanding pass-through. Auer and Schoenle [2016], Broda and Weinstein [2006] and Gopinath and Rigobon [2008] are well-known examples of exchange-rate pass-through analysis using import price microdata.

Perhaps Frankel et al. [2012] offers the first systematic study of exchange-rate pass-through with disaggregated consumer price data. The authors use data from narrowly defined commodities and find a rapid downward trend in the degree of pass-through in developing economies. Moreover, Frankel et al. [2012] support the importance of local (distribution and retailing) costs in pricing-to-market, in addition to the monetary environment.

More recently, studies by Antoniades and Zaniboni [2012] and Aron et al. [2014] analyse exchange rate pass-through to consumer prices with datasets from United Arab Emirates and South Africa (SA), respectively. Using scanner data collected in supermarkets, Antoniades and Zaniboni [2012] exploit the average price change to estimate ERPT and report an aggregate pass-through of around 20% after one year. Moreover, Aron et al. [2014] document considerable differences in short- and long-run pass-through responses across product-categories. For example, food items display higher pass-through than health care items or garment. After weighting their estimates by SA's CPI weights, the authors find that pass-through after 12 months for the CPI components covered in their study is estimated at 18%, near the upper end of earlier studies on aggregate CPI data for SA.

The microdata studies above mentioned are a key input in our econometric framework. The empirical approach followed in microdata studies is substantially different from traditional ERPT analysis based on price indices. In the later, researchers commonly rely on vector error correction models (VECM), e.g. Fue [2012];

[1]See, for instance, Goldberg and Campa [2010] and Fue [2012] for analysis based on consumer and import price indices respectively. For Mexico, Capistran et al. [2012] study exchange rate pass-through to import, producer and consumer price indexes using a vector autoregressive model (VAR). Their results show that the pass-through to import prices is complete but only around 20% for consumer prices. Furthermore, Cortes [2013] reports that the exchange rate pass-through to headline CPI is low and not statistically significant. However, pass-through is positive and significant for the non-services subindex.

while the former use of panel-data style frameworks as items are followed through time e.g. Gopinath and Rigobon [2008].

Turning now to the heterogeneity across economies and industries, it is important to recall that one of the contributions of this research is to provide evidence that ERPT is not homogeneous (within the country) as it is commonly assumed.

Regarding the first dimension in our analysis, different pass-through rates across economies, is not new in cross-country studies. In fact, two pieces above mentioned address this dimension. Goldberg and Campa [2010] employs a sample of OECD countries, while Fue [2012] focus on Euro zone. However, OECD countries differ in different axis- politically (protectionism and regulations) and economically (exchange rate volatility, inflation rate, import bundle). Thus, changes in pass-through rates might be explained by a number of country-specific characteristics interacting at the same time. Even in a monetary union without direct border effects between member states, like in the Euro zone, differences in fiscal policies, market structures, as well as consumption patterns are likely to play a role in price-setters decisions.

We expect these cross-country differences to be less of a problem using regional Mexican data since taxation and regulation authorities are the same for all state members. Related to regional analysis in Mexico, studies by Castillo-Ponce et al. [2013] and Castillo-Ponce and Hernández [2008] offer a comprehensive analysis of Mexico's inflation dynamics with respect to foreign factors. Castillo-Ponce and Hernández [2008] suggest that relative wages and exchange rate variations are major drivers for price levels in Mexico. Additionally, Castillo-Ponce et al. [2013] analyse pass-through for seven areas in Mexico and show that in four out of them the Peso-Dollar exchange rate have a common cycle with the area's inflation rate. However, these papers fail to formally test potential determinants driving heterogeneous responses. The microdata used in this paper allows to estimate pass-through in 46 different regions and test whether local characteristics shape these responses.

Regarding the second dimension in heterogeneity, different rates of pass-through across industries, there has been an increasing and growing amount of literature addressing industry characteristics to explain heterogeneous levels of pass-through to consumer prices. Nakamura and Steinsson [2008] document that changes in commodity costs affect manufacturer and retail prices for the coffee industry and estimate a 20% pass-through to retail prices. Goldberg and Hellerstein [2013] explore ERPT of the beer market from a large US supermarket chain and document an average 40% pass-through. Moreover, focusing on costs pass-through (and not precisely on exchange rate pass-through), Misra et al. [2010] estimates an instantaneous pass through of 67% and full pass through one period later. Furthermore, Goldberg and Verboven [2005] analyse car prices in Europe and find strong evidence in favour of the Law of One Price.

Hence, industry-specific pass-through literature leans towards heterogeneous responses across industries. Given the wide range of type of items observed in our sample, we expect to find industry heterogeneity as well. Additionally, and in contrast to much of the pass-through literature, this paper provides estimates of non-tradable services, which potentially use imported inputs in their production. Thus, we would expect to observe pass-through heterogeneity between and within tradable and non-tradable goods and services.

Another significant aspect addressed in the pass-through literature are the channels contributing to pass-through differentials, across countries and/or industries. That is, aside estimating the degree of pass-through, the debate has shifted to recognise the determinants of such levels.

A number of explanations stand in the literature. From the macro perspective, monetary policy conduction (Engel [2002]; Devereux and Engel), exchange-rate volatility (Frankel and Saiki [2002]; Capistran et al. [2012]) and inflation rate (Gagnon and Ihrig) are among the potential factors driving the response of inflation to exchange rate shocks. Relative to micro aspects, distribution costs (Goldberg and Campa [2010]; Burstein et al. [2003]), markup adjustments (Chen and Juvenal [2016]; Atkeson and Burstein [2008]; Nakamura and Zerom [2010]), product differentiation (Auer and Chaney [2009]; Broda and Weinstein [2006]; Bussiere and Peltonen [2008]), market structure (Auer et al. [2014]; Beck et al. [2009]) and import intensity (Gopinath et al. [2010]; Campa and Goldberg [2005]; Devereux et al. [2004]) are commonly recognised as pass-through determinants.

This paper sheds further light on the micro side. Using a micro-dataset from 46 well-defined urban regions and 58 industries in Mexico, we investigate if the characteristics like distribution costs, market competition, economic development, demand conditions, price volatility, import intensity or expenditure share are associated with consumer price responses to exchange rate shocks.

3.3 Data

In what follows, the datasets used in this study are described. Firstly, the micro-data sample utilised for estimating ERPT responses; and secondly, the aggregate variables acting as potential pass-through determinants.

3.3.1 Price data

This project exploits a large micro-dataset gathered by the Bank of Mexico and used to calculate the Consumer Price Index (CPI) in Mexico. The original dataset comprises more than 18 million price records collected over a 205 semi-monthly periods from the second half of June 2002 to December 2010.[2]

The geographical coverage and product-categories included in the micro-price sample are dictated by the 2000 National Survey of Households' Income and Expenditures (Encuesta Nacional Ingreso y Gasto de los Hogares, ENIGH) conducted by the National Institute of Statistics and Geography (INEGI) of Mexico. Results from the household survey ensure that the CPI measures the price evolution of a representative basket of goods and services consumed by an average Mexican household.

For this price survey, around 100 Banxico employees in 46 urban regions across Mexico visited more than 20,000 retail outlets on a regular basis.[3] A wide range of outlets were visited, from grocery stores, pharmacies, street-markets, furniture shops, shoe stores, hospitals, auto dealerships, etc.

One of the survey's main principle is that each price record corresponds to a precisely defined item. That is, each price collector had detailed checklists describing the items to be priced. For example, *Cookies, brand X, box with 4 packages, 500 gr., at retail Y*. This principle provides the price history of individual goods. The unbalanced panel structure draws the price history of around 65,000 items.

Importantly, we observe the same product-categories (basket) across cities but for each product-category we observe a sample of goods that might vary across regions. In order to keep the CPI representative, price collectors were advised to price the most common brands and varieties. Hence, some product categories are relatively similar across cities (e.g. soft drinks pricing Coke or Pepsi) but some other are not (e.g. women trousers).

Given confidentiality policies between Banxico and price informants, our dataset provides only few items' characteristics. For each item we observe (i) a unique identification code per item, (ii) the region where the price was observed, (iii) the product-category it belongs to and (iv) individual price index.[4] Products'

[2] The time window of the study is dictated mainly by major modifications in the CPI's basket and methodology. Prior the 2002 base-year and after December 2010, weights, methodology and basket of goods were updated. These breaks in the data make it difficult to compare samples for statistical analysis.

[3] Source: www.banxico.org.mx

[4] Product-category in our sample is similar to BLS's ELI in the US or ONS's COICOP classes in the UK.

details like brand, quantity/size, name or type of the outlet are not reported. In addition, we do not observe nominal prices but individual price indices assigned to each item. All individual indexes are set at 100 in the first time-wave. Subsequently, each index reflects the price variation of a particular product from one wave to the next one. Explicitly, each individual index is calculated as the ratio between the current and previous price multiplied by the index from the last wave. As one of the main objectives of this work is to evaluate the share of exchange rate fluctuations passing-through consumers, working with (log) differences instead of (nominal) levels is not a limitation. Figure 3.1 depicts an example of the data available.

Despite the original semi-monthly frequency reported, this research is based on monthly price changes. The majority of prices do not change every week (Kle), and thus using semi-monthly differences would result in an overwhelmingly number of zero observations. In a similar study to ours, Aron et al. [2014] utilise 6-month variations. In this paper, however, we consider that 6-month differences omit relevant exchange rate dynamics.

We now move on describing the 2 main dimensions used in our analysis, the regional and industry coverage. Regarding the first one, figure 3.2 illustrates the survey's geographical coverage. As it can be seen from the map, observed locations are fairly distributed in the Mexican territory. The price survey provides prices from large cities, such as Monterrey, N.L. or Guadalajara, Jal. with over 3 million inhabitants, and small urban areas like Tehuantepec, Oax. or Jacona, Mich. with around 100 thousand inhabitants. Since we are interested in studying heterogeneous ERPT within the country, prices from the 46 regions are included in the analysis. These urban areas provide an excellent setup for our analysis.

With respect to the second one, the original dataset reports observations classified in 315 product-categories. Just to mention a few examples of product-categories, we observe prices of chocolate bars, women trousers, toilet paper, cinema entry, hair cut fee, etc. We neglect 76 product-categories. These categories are either associated with prices regulated by the government (e.g. gasoline or electricity fees), reported as weighted averages (e.g. accommodation services) or their prices heavily vary upon weather conditions (e.g. tomatoes). After discarding these categories, the micro-data sample comprises 239 product-categories.

An important transformation in our data is that we cluster product-categories by the North American Industry Classification System (NAICS). The matching table between product-categories and the NAICS classification is detailed in Banxico's CPI methodology handbook.[5] Working with NAICS industry codes allows us to link

[5] "Documento metodológico del INPC", Banco de Mexico, 2002.

our pass-through estimates to regional and industry characteristics extracted from other national surveys. In total, we end up with 58 NAICS industries, which we would refer simply as industries form this point on.

The micro dataset used in this analysis has three main limitations for accurately measuring price variations. We first list the limitations and then we discuss the potential effects in our estimates.

Firstly, no variable in our micro-data flags out if the item was effectively observed or if it was out of stock. In case of the latter, the methodology at the time indicated to fill in missing values with the last observed price. Therefore, our dataset limits the number of false price variations by reporting zero price change in case the item was out of stock.

Secondly, there are no flags indicating when the item was substituted from the sample. Similarly as above, our dataset reports zero price variation. Again, it is not possible to identify when a unit was replaced but false price variations from invalid goods' comparisons are kept to the minimum. At the time of this survey, the Bank of Mexico listed the items exiting the survey and their substitutes every month. Personal estimates point to a 1% monthly turnaround.

Thirdly, numerous studies have discussed how temporary sale prices affect studies analysing nominal frictions.[6] Sale prices are not identified in the dataset. Therefore, all prices are treated equally in our analysis (regardless if they are regular or potential discount prices). Although the methodology used by Banxico for collecting the current data accepts sale prices to be included in the sample, price collectors are instructed not to report clearance sale prices as the quality of the product might have changed.

The first two issues downward bias our estimates. The reason is that we are including missing values as zero price variations in our estimates. Our econometrical framework primarily focuses on monthly price variations and, as previously addressed, only about 2% of our monthly observations might be affected by these measurement errors. Hence, we expect these two sources of bias to have limited impact in our estimates. The third issue upward biases our results. The intuition is that a sale price (or recovery from sale) induce a price variation not related exchange rate fluctuations. Unfortunately, without a sales indicator, it is hard to assess how many prices on average are transitory. In order not to intervene in our key dependent variable (magnitude of price changes), we do not utilise any kind of adjustment regarding sale prices.

[6] As documented by Kle, Nakamura and Steinsson [2008], and Mackowiak and Smets [2008], an important number of price changes are temporary discounts. Nevertheless, Romer [2011] argued that frequent sales could be seen as a symptom of a weak economy.

With respect to accurately measuring ERPT, our dataset presents one caveat. We are unable to identify whether an item is imported or it was produced with imported inputs. Hence, our results might not represent the most precise pass-through estimation but they can be considered as the average price response to exchange rates variations.

As treatment of outliers, we drop the 1^{st} and 99^{th} percentiles of price variations for each industry. We believe that neglecting outliers by industry is a better approach (than the pooled 1^{st} and 99^{th} percentiles) given the degree of heterogeneity in price variation by industry.

3.3.2 Aggregate data

For the first stage of our analysis, we use the Real Exchange Rate (RER). The RER is calculated using the Nominal Exchange Rate (NER) and Mexico's CPI, published by Banxico, as well as the US's CPI, distributed by the Bureau of Labor Statistics (BLS). We obtain the RER as the ratio between the American and Mexican CPIs multiplied by the NER, defined as MXN Pesos per US dollar. We depict these variables in figure 3.3 and figure 3.4. An increase in these figures implies a depreciation of the Mexican Peso.

The use of RER, instead of NER, is standard practice in the pass-through literature. See, for instance, Gopinath and Rigobon [2008] or Goldberg and Campa [2010]. Moreover, Burstein and Gopinath [2014] document that the RER co-moves closely with NER at short and medium horizons. Indeed, figure 3.4 shows similar dynamics for both exchange rates in Mexico.

Despite RER and NER similarities, we conduct robustness checks using NER and our results change quantitatively but not qualitative: regional heterogeneity is still present in our pass-through estimates. Additionally, we use the Effective Exchange Rate (EER), distributed by the Bank of International Settlements (BIS), as an alternative explanatory variable and our main conclusions do not change.[7] For concreteness, we report estimations using RER as our explanatory variable only.

For the second stage of the analysis, we associate ERPT elasticities to regional- and industry-specific characteristics. Hence, a range of economic indicators from two main sources are compiled. In this section we provide an outline of the consulted surveys and leave the detailed definition and expected effect for the empirical section 3.5.

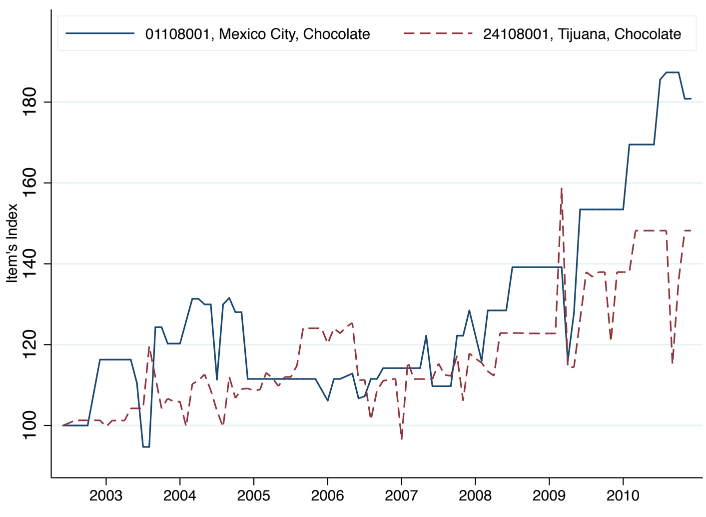
[7] See Appendix for a graphical comparison between RER and EER. Recall that the EER is a trade-weighted exchange rate. Hence, the close relationship between these exchange rates is due to the fact that two thirds of Mexican imports come from the US (over the sample period).

First, the 2004 and 2009 Economic Census, conducted by INEGI, are the main source of economic data related to regional- and industry-specific characteristics. The census cast information from every agent (firm) carrying out any economic activity at the time in Mexico.[8] Among the many variables reported, the census provides the number of economic agents, number of employees, wage bill, output, input costs, investment, electric consumption, building permits, length of pavement roads, number of students in elementary school, etc.

The economic census provide granular geographic data at the municipality level.[9] Hence, the covariates used in our analysis represent actual pictures of a well-defined (urban) economy. For instance, if we observe prices in two or more urban regions in the same state (e.g. the capital city and another small town), our covariates effectively capture these differences. In total, data from 277 municipalities are used to describe 46 regions and 58 industries.

Second, we use the 2008 Input-Output Matrix, also distributed by INEGI, as it offers comprehensive industry data. That is, we are able to derive proxies on the cost structure. In other words, we can approximate inputs' import intensity, share of imported final goods, transportation costs, capital and labor intensity, etc.

Figure 3.1: Example of price dynamics



[8]See INEGI [2009] for the complete census framework and methodology.
[9]Mexico's economic and political system is organised in three layers: national, state and municipal. Municipalities can be seen as US counties or as UK councils.

Figure 3.2: Observed regions

Figure 3.3: Annual inflation

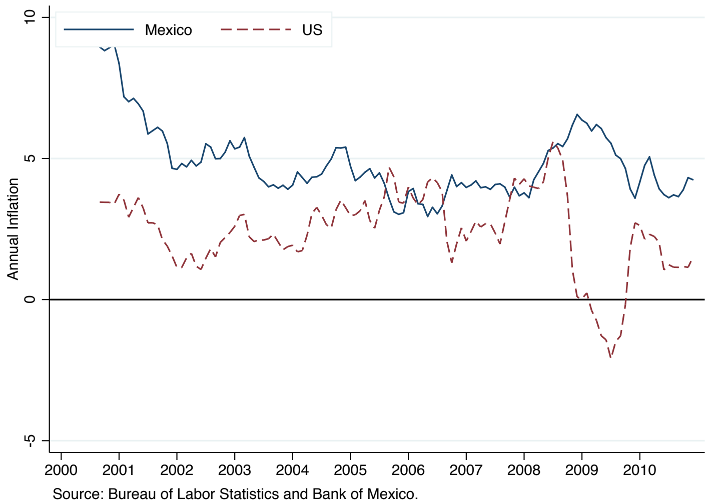
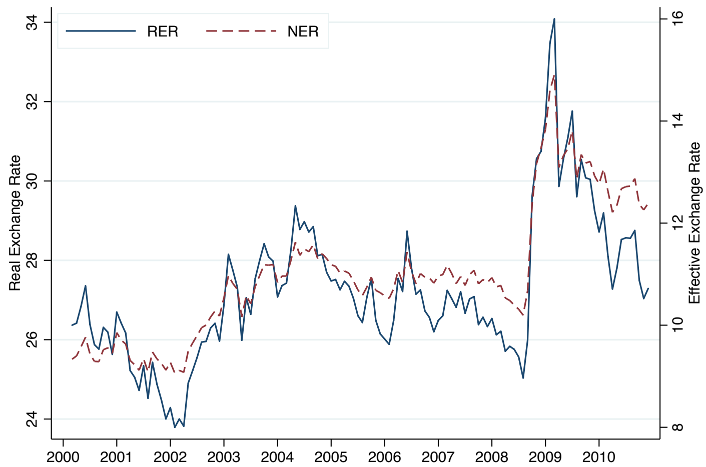


Figure 3.4: MXN Peso - US Dollar Exchange Rate



Source: Bank of Mexico.
An increase indicates a depreciation of the MXN Peso.

3.4 First stage: ERPT micro-specification

Exchange Rate Pass-Through is the percentage response of domestic prices to exchange rate changes. If the effect of the depreciation is fully reflected into prices, then pass-through is said to be complete. If only a small percentage of the depreciation is reflected, then the pass-through is described as partial or incomplete. This definition, however, casts some difficulties when measuring ERPT.

First, the type of prices considered in the analysis. This study exploits price dynamics from a wide range of tradable and non-tradable final goods and services. Although price responses to exchange rates shocks are less evident as one moves along the production line, industry specific studies by Nakamura and Zerom [2010] and Chen and Juvenal [2016] show high pass-through rates to final consumer prices.

Second, prices may or may not react immediately after exchange rate shocks. Differences between short-run and long-run pass-through can be explained from different angles. For example, inventory depletion, menu-cost and price stickiness and/or exchange rate shocks persistence might delay exchange rate effects. Hence, we utilise a framework that allows calculating pass-through elasticities at different time horizons.

Third, price changes are not purely explained by exchange rates fluctuations. Indeed, domestic and foreign factors affect pricing decisions (e.g. labour costs). In order to keep our framework parsimonious, our benchmark specification makes use of national, regional, industry, price category, monthly and yearly fixed effects. Since our dataset is very granular and with over 100 months, fixed effects capture common factors determining prices other than the exchange rate.

Fourth, since one of our main goals is to assess whether pass-through is heterogeneous for different types of goods and services, the empirical strategy must account for such heterogeneity. In fact, theory suggests that ERPT may vary depending on how tradable goods and services are. Presumably, services display lower pass-through rate due to their considerable local component; whereas the tradable sector tends to react more to exchange-rate changes as (i) goods might be imported or exported, (ii) imported inputs are used in production or (iii) compete against imported goods. Thus, we analyse the complete set of industries in our dataset as a whole, but we also provide results on these 2 broad categories: tradable and services.

Lastly, under inflation-targeting regimes, like the one prevailing in Mexico, exchange rates and domestic inflation are jointly determined. This assumption might be problematic for time-series analysis. However, this endogeneity issue is less of an problem using micro-data since it can be argued that the exchange rate is not affected by individual firms' pricing decisions. Nevertheless, our benchmark estimates drop the contemporaneous RER change as a precautionary measure.[10]

3.4.1 Empirical approach

Moving into the econometric specification, we have to bear in mind that one of this paper's aims is to show uneven ERPT rates in Mexico. Since our data provides price dynamics of individual items in a number of industries across different regions in Mexico, our econometric approach must be flexible enough to capture the industry-region heterogeneity.

The estimation of ERPT follows a standard pass-through regression common in much of the literature. For every month t, the change in log prices, $\triangle p_t^{i,j,k}$, and RER, $\triangle RER_t$, are calculated. Then, the monthly difference in individual prices is regressed on lags of the interaction between $\triangle RER_t$ and regional dummies. The estimated model for each of the 58 industries is:

$$\triangle p_t^{h,i,j,k} = \sum_{n=1}^{m} \beta_{j,k,t-n}[\triangle RER_{t-n} * \omega_k] + \alpha_i + \omega_k + \lambda_t + \varepsilon_t^{h,i,j,k} \tag{3.1}$$

[10]Including contemporaneous RER variations into our calculations do not alter the main conclusions of this chapter.

where $\triangle p_t^{h,i,j,k}$ is the log change in the price of good h, which belongs to price-category i and industry j, observed in region k at month t. $\triangle RER_t$ is the monthly log difference between RER at time t and $t-1$. We include year and month fixed effects (λ_t) controlling for aggregate shocks, policy modifications or adjustments in labour costs affecting the overall economy. Regional dummies (ω_k) capture local specific characteristics determining price formation. Product category (α_i) controls for product-category heterogeneity within the industry. Error terms are clustered at city level, allowing correlation through time.

Cumulative pass-through after m months for industry j in region k is defined as

$$\beta_{j,k,m} = \sum_{n=1}^{m} \beta_{j,k,t-n} \tag{3.2}$$

We report results for $m = 6$, 12, 18 and 24 months horizon.

All in all, for each horizon m we have a pool of 2,668 estimates of $\beta_{j,k,m}$.[11] For concreteness, results summarised in section 3.6 concentrate on single pass-through measures by region or industry and the heterogeneity found across them. These measures are defined as

$$\beta_{k,m} = \sum_{j=1}^{58} \psi_{j,k}\beta_{j,k,m}, \qquad with \sum_{j=1}^{58} \psi_{j,k} = 1 \tag{3.3}$$

$$\beta_{j,m} = \sum_{k=1}^{46} \eta_{j,k}\beta_{j,k,m}, \qquad with \sum_{k=1}^{46} \eta_{j,k} = 1 \tag{3.4}$$

That is, these measures of pass-through are calculated as the weighted average of industries' (regions') pass-through per region (industry). The weights used for this analysis are the actual CPI weights used by the Bank of Mexico for CPI calculations.

Although equation 3.1 is a standard pass-through regression based on micro-data, we tried alternative specifications. For instance, the inclusion of a common term $\sum_{n=1}^{m} \beta_{h,k,t-n} \triangle RER_{t-n}$ in equation 3.1. In other words, adding a regressor capturing the overall pass-through to our benchmark model. The inclusion of these terms do not alter $\beta_{j,k,m}$ magnitudes whatsoever. Alternatively, we can use the NER or EER as explanatory variable. Results suffer from quantitative but not from qualitative changes. Hence, only estimates from the benchmark specification are summarised in section 3.6 for brevity.

Under floating exchange rate in an inflation-targeting regime, like the one

[11] 58 j-industries x 46 k-cities.

prevailing in Mexico, reverse causality between the exchange rate and domestic inflation might be a concern of endogeneity. However, it can be argued that pricing decisions of an individual (independent) firm cannot influence the exchange rate by itself. This argument is commonly used in the trade literature using microdata. See for instance Chen and Juvenal [2016] and Aron et al. [2014].[12] Nonetheless, as a precautionary measure, our benchmark estimates drop the contemporaneous RER change. That is to say, lagged RER is exogenous to current pricing decision. Including contemporaneous RER variations into our calculations do not alter the main conclusions of this chapter.

3.5 Second stage: ERPT Drivers

One of the novelties of this research is that we observe a fairly homogeneous basket of goods and services across a number of regions. This unique industry-region context is exploited to assess likely factors determining the degree of pass-through. In fact, recent pass-through studies link price responses to local factors of importing economies (e.g. Fue [2012] and Goldberg and Campa [2010]). This chapter is similar in spirit but it alleviates obvious issues of different institutional frameworks and tastes between countries by looking at within country responses.

In this section, we first specify the econometric approach, then we provide an extended description for each of these drivers and their likely effect on pass-through.

3.5.1 Empirical approach

The following pass-through determinants are examined: distribution cost (Z^1), market power (Z^2), local demand (Z^3), economic development (Z^4), import intensity (Z^5), price flexibility (Z^6) and expenditure share (Z^7).

Two precisions are necessary in this second step. First, since ERPT estimates act as dependent variables, pass-though coefficients are weighted by the inverse of its standard error. Second, results are considered suggestive in nature due of the lack of structural identification of factors.

In order to assess the role of potential pass-through drivers, we regress the pass-through elasticities (2,668 observations) on the potential drivers. For concreteness, let $\hat{\beta}_{j,k,m}$ denote the ERPT elasticity as defined in equation 3.2 (weighted by the inverse of its standard error), and $Z^1_{j,k}$, ..., $Z^7_{j,k}$ are the set of stationary

[12] Exogeneity of the exchange rate is more of a concern when using aggregate macroeconomic variables using time-series frameworks.

covariates previously listed. The fitted model is:

$$\hat{\beta}_{j,k,m} = \delta_0 + \delta_1 Z^1 + ... + \delta_7 Z^7 + u_{j,k,m} \tag{3.5}$$

Notice that the independent variables are either region and/or industry specific and do not vary depending the horizon in place. Standard errors are clustered at regional level.

Similarly as in the previous section, we tried different specifications. For instance, instead of using all industry-region pass-through estimates as dependent variable, we can use the aggregate regional $\beta_{k,m}$ described in equation 3.3. However, this specification would only have 46 (regional) observations and results are not robust.

3.5.2 Pass-through determinants

Each of the covariates and their expected effect on ERPT are summarised below. They represent different aspects of the regional economy, most of which are macro but can be easily linked to micro issues. Table 3.1 displays the correlations between the regional covariates. The correlations show weak correlation between them.

Distribution costs

One potential channel explaining asymmetries in pass-through levels are local distribution costs, as discussed in Goldberg and Campa [2010] and Nakamura and Zerom [2010]. Intuitively, the greater share of distribution costs is into the final price, the less responsive prices are to exchange rate fluctuations.

This assumption holds only if transportation costs are invariant to exchange rates. This supposition might be in place in Mexico since fuel prices (main input in distribution costs) were fixed by the government during the years of study.

Considering the geographic proximity between Mexico and the US, this paper considers the average distance from region k to border cities as a proxy of distribution costs. By taking the average distance to these cities, it is assumed that import flows are equal across them.[13] The urban regions taken as imports' access points are Cd. Acuna, Coah.; Cd. Juarez, Chih.; Matamoros, Tamps.; Mexicali, B.C. and

[13] The original analysis considered the distance from city k to its closest north border city. However, taking only one border as reference implies that all city's k imports have a unique import source. Under this approach, and given Mexico's highway network, 38 out of the 46 regions in the sample take Matamoros, Tamp. as their only import source, which is unlikely.

Tijuana, B.C.[14] The main reason for not extending the number of border cities in the analysis is that no price data would be available for ERPT comparisons.

Taking the distance to the north border as a proxy of transportation costs, one would expect that regions closer to the U.S. border have lower transportation costs, and thus higher ERPT rates.

Market Density

Firms' market density, associated with the local structure of retail competition, may play an important role in explaining heterogeneous price responses of similar goods in different regions. Nonetheless, the relation is ambiguous. On the one hand, price-setters facing high retail competition might have less market power, and thus pass less exchange rate fluctuations to final consumers. On the other hand, retailers in a competitive market charge lower markups, implying a greater proportion of the final price depends on exchange rates, and thus higher pass-through.

The degree of competition is often refered in the literature as a pass-through determinant. For instance, Antoniades and Zaniboni [2012] analyse supermarkets' market shares in the United Arab Emirates (UAE) and find that pass-through increases with retailer market power.

In this paper, market power is approximated in terms of market density. Based on INEGI's census data, market density is then defined as the number of firms in the retail sector relative to the labor force in the region.[15] Market density aims to capture regional market competition. In principle, higher market density implies a greater number of firms offering products relative to the number of consumers. As consumers have more retailers to choose from, firms face a greater degree of market competition.

Demand conditions

Theoretical pass-through models by Corsetti et al. [2005] and Choudhri and Hakura [2006] frame demand conditions as an important driver. The argument is similar to that in the Mundel-Fleming workhorse model. A positive demand shock leads to a currency appreciation, therefore price increases. Hence, favourable demand conditions might ease passing exchange rate fluctuations to consumers and not having to

[14] Tijuana, B.C. is located at the west coast; Matamoros, Tamps. is situated on the far east; while the cities of Cd. Acua, Coah.; Cd. Juarez, Chih. and Mexicali, B.C. are located along the border line.

[15] Alternative specifications might be: urban surface (Km^2) instead of the number of firms or population as normalising factor. Our proxy does not seem to change drastically.

adjust markups. Therefore, we would expect to find a positive correlation between demand and pass-through rates. If otherwise, think of a case that in the light of demand growth, firms try to fill in the gap in demand by absorbing exchange rate fluctuations in their markups and keep up with the "good time".

We utilise regional GDP growth as a measure of demand conditions. This business cycle variable is defined as the difference between the logs of regional output in the trade sector between 2008 and 2003, at constant prices.[16] The cities with the highest increase were Tlaxcala, Tlax (66.54%) and Veracruz, Ver. (63.50%), while Jacona, Mich. (8.62%) and Oaxaca, Oax. (10.70%) reported the lowest expansion in the retail sector.

Economic development

Economic development has been considered as a potential driver for asymmetric responses in local inflation to nation-wide cost shocks (steaming from exchange rates fluctuations, for instance). Presumably, less developed regions have less developed infrastructure and are less integrated with commercial routes, hence lower pass-through. In an influential paper, Campa and Goldberg [2005] stress that changes of pass-through rates in developing economies might be explained indeed by a shift in consumption composition. Therefore, we would expect to find a positive correlation between this covariate and pass-though elasticities.

Following Beck et al. [2009] and Kose et al. [2003], this paper utilises the size of the local services sector as a proxy of economic development in the region. Greater share is interpreted as a more developed region. In other words, if the share of services is low, it means that the region's main economic activities are orientated towards primary or secondary activities. The most and least developed regions are Mexico City (57.7%) and Tehuantepec, Oax (4.42%).

Import intensity

In cross-country analysis using aggregate data, Goldberg and Campa [2010] focus on the role of imported inputs transmitting exchange rate fluctuations into consumer prices. Not surprisingly, they find that price sensitivity arises because imported inputs are used in production of home non-tradable goods or services. Therefore, we would expect to find a positive correlation between our import intensity proxy and pass-through estimates.

[16] Regional GDP at this level of disaggregation is only reported by INEGI every 5 years. The 2013 figure is out of our price sample period.

To investigate this claim, we compute the ratio of private consumption of final goods with foreign origin relative to total private consumption of final goods (by industry). This data is obtained from the 2008 Input-Output Matrix compiled by INEGI. Despite the fact that this variable is only observable at industry level, and not at regional level, it allows to study whether ERPT rates are systematically higher in industries with greater imports share, regardless the region. We observe industries like computer equipment with over 99% import share, while domestic personnel and accounting services use less than 1% of imported inputs.

Price change dispersion

Studying heterogeneity of import prices and exchange-rate pass-through, Berger and Vavra [2013] document a strong positive relationship between price change dispersion and exchange rate pass-through. Intuitively, if price-adjusters respond less strongly to cost shocks, it should be expected that these price changes exhibit lower dispersion and lower pass-through. Berger and Vavra [2013] report that this correlation is robust at the cross-sectional and at the time-series level.[17]

For this purpose, we use the standard deviation of price changes (given a price change) per industry per region as a measure of price dispersion. Under this proxy, it is assumed that the industry-region price dispersion is constant over the period of study. On average, the fertilisers and pesticides exhibited the highest price dispersion (7.51%). In contrast, automobiles showed the lowest price dispersion (1.79%). Moreover, Huatabampo, Son. (2.93%) and La Paz, B.C. (6.34%) displayed the lowest and highest regional price dispersion across industries

Expenditure share

We explore the possibility that industries associated with large shares of consumers' expenditure exhibit higher pass-through. In principle, if consumers spend a large fraction of their income on these goods and services, one might expect that these industries are more likely to have greater elasticity of substitution. Theory suggests that a high elasticity of substitution dampens firms' incentives to pass-through exchange-rate variations.

In this case, we use industry CPI weights as a proxy for expenditure shares. Indeed, the CPI weights used by the Bank of Mexico come from the largest household

[17] In a similar study, Gopinath and Rigobon [2008] find that the frequency of price changes is positively correlated with pass-through estimates. Although we calculate different frequency of price adjustment measures, we did not find any statistically relevant correlation between these to statistics.

expenditure survey in Mexico. Although we must recognise that these weights suffer from the plutocratic caveats widely known in price indices, we believe these weights are still representative of the Mexican households' consumption shares.

Additionally, a potential correlation between CPI weights and pass-through has policy implications. In case of a positive correlation, the Mexican CPI would be particularly sensitive to exchange rate fluctuations. Hence, Mexican monetary authority, under inflation targeting, might pay special attention to the exchange rate.

For this proxy, the industries with the lowest and highest CPI shares (on average across regions) are repairs of household appliances (0.01%) and restaurants (6.88%) respectively.

Table 3.1: Region-specific correlations between potential ERPT drivers

	Km to NB	Output Growth	Development	Market Density
Km to NB	1	0.3959	0.2308	0.4725
Output Growth		1	-0.1499	0.2392
Development			1	-0.1807
Market Density				1

3.6 Results

3.6.1 Heterogeneous ERPT

We first focus on the first question of interest, is exchange-rate pass-through uniform across regions in Mexico? In contrast with previous cross-country studies, our novel data set allows interesting within-country ERPT comparisons.

Table 3.2 reports the 46 regional ERPT estimates. That is, as defined in expression 3.3, regional estimates are calculated as weighed sums of region-industry pass-through rates using CPI weights distributed by the Bank of Mexico. We provide 6-, 12-, 18- and 24-moths cumulative pass-through elasticities. As a visual tool for our results, the content of table 3.2 is depicted in graph 3.5.

Focusing on the 6 months pass-through horizon in column 1 of table 3.2, we notice that the urban area with the lowest pass-through rate is Oaxaca, Oax. (0.045**). Oaxaca's rate is more than 4 times lower than the highest pass-through region La Paz, B.C.S. (0.197***). A Wald test confirms that the difference in pass-through rates between these 2 regions is statistically significant (p-value 0.000). Of 46 regions available, 39 report pass-through elasticities statistically significant different from zero; and all of them statistically different from full pass-through.

Turning now for the responses after one year, we observe another interesting result related to heterogeneity. Cumulative pass-through grows at heterogeneous rates. For instance, Tijuana, B.C. reports a nearly 10% reduction (from 0.147*** to 0.134**), while Monterrey had a 80% increase in its pass-through rate (from 0.093*** to 0.167***). After 12 months, the regions with lowest and highest pass-through rates are Tampico, Tamps. (0.089*) and La Paz, B.C.S (0.287***) respectively. Similarly as in the 6 month horizon, we find that the difference between these 2 regions is statistically significant (p-value 0.028).

When 24-months horizon is calculated, column 4 in table 3.2 shows that pass-through estimates become less precise as standard errors become wider. From the 46 regions available, only 15 report pass-through elasticities statistically different from zero; and all of them are statistically different from one. Monterrey, N.L. is the region with the lowest pass-through after 24-months (0.170*) and Fresnillo, Zac. is the highest (0.348***). Although point estimates are still in a 1-to-3 proportion, the difference between these 2 regions is no longer statistically significant (p-value 0.127). Furthermore, by looking at column 4, we notice that some statistically insignificant even revert back to zero. We interpret theses results as evidence that, as one starts looking at longer horizons, our microdata framework does not account for potential long-term effects properly.

Therefore, we find sufficient evidence that regional price responses to exchange rate shocks are asymmetric across Mexico. Focusing only on tradable goods (i.e. neglecting services), point estimates also indicate that pass-through is heterogeneous across regions and at different time horizons. We leave in the Appendix additional figures focusing only on tradable goods' pass-through elasticities for the curious reader.

It is worth noticing that we find heterogeneous pass-through for different industries. These estimates are calculated using expression 3.4 and summarised in table 3.3 at our 4 time horizons. Similarly as in our regional analysis, we plot the elasticities from table 3.3 in figure 3.6 to facilitate the analysis. Most tradable goods exhibit well behave pass-through elasticities: positive, statistically significant, and increasing over time. In contrast, most non-tradable services show statistical insignificant results. Exception of services exhibiting ERPT effects are *General hospitalisation* and *Maintenance of automobiles*. The use of imported inputs into these non-tradable services may partially explains this result. However, this finding is at odds with pass-through theory suggesting that non-tradable services do not react to exchange rate shock.

3.6.2 Drivers

We turn now to our second question of interest, what are the likely drivers of the heterogeneous pass-through rates? Results from model 3.5 are summarised in table 3.4. Additionally, since price-setters from tradable goods and non-tradable services might pass-through exchange rate effects differently, table 3.5 and table 3.6 offer regressions' results for these two main categories separately.

We first start describing results in table 3.4 using the complete pool of industry-region estimates. The distance to the north border exhibits a positive statistically significant up to the 18-months horizon relationship with pass-through elasticities. In other words, regions located farther from the border tend to pass a higher share of exchange rate fluctuations into their consumers.

This result is at odds with what theory and evidence suggests regarding distribution costs. Thus, distance to the US border is likely to be a poor proxy for distribution costs. The obvious explanation might be that our proxy does not capture the possibility that distribution costs vary per type of good, industry and location.

We can think of this finding in two different directions on why regions away from the border report greater price variations in response to exchange rates fluctuations. One is related to Mexico's particular geographical location. Although goods being sold closer to the border have a lower distribution cost, consumers can cross the border avoiding changes in their purchasing power. As consumers live further away from the north border, the exchange rate effects are pass-through by firms after incorporating transportation costs. This explanation can bring a new idea into discussion since previous studies have mainly focused on countries like the US and Europe. In these papers, consumers can get closer to docks but cannot actually cross to the origin country. Another potential explanation for this finding is that border firms edge from exchange rate fluctuations. That is, border firms maybe engage into longer term contracts with their suppliers than firms situated further away from the border. Unfortunately, neither of these two hypothesis can be fully addressed with our current dataset.

Moreover, we find that market density has a negative relationship with pass-through rates. Remember from section 3.4, market density is used as a proxy of market power and its effect is unambiguous. Our results suggest that, the more economic agents per capita are, and hence more competition, firms find difficult to pass-through exchange rate effects into prices. However, we must acknowledge that describing market competition in a particular region is a difficult task. A wide variety of products and services, produced from different industries and inputs, are offered to consumers. Therefore we interpret these results as suggestive.

Table 3.4 also shows that output growth and development are not correlated with the industry-region pass-through elasticities. Output growth as a proxy of demand conditions is statistically insignificant. Hence, our results are inconclusive relative to the positive relationship argued by Corsetti et al. [2005] and Choudhri and Hakura [2006]. Also, economic development seems not to be correlated with the exchange-rate pass-through, as found by Beck et al. [2009] and Kose et al. [2003].

Furthermore, table 3.4 shows that import share has a positive relationship with pass-through rates. In line with Goldberg and Campa [2010] and Frankel et al. [2012], we find that industries with greater import intensity systematically exhibit greater pass-through rates. Import intensity explains the degree of pass-through at different time horizons.

In addition, we find that price dispersion at item-level price changes is positively correlated with the 6-months exchange-rate pass-through estimates only. This result supports partially Berger and Vavra [2013] and Gopinath and Rigobon [2008] arguments that items responding less strongly to cost shocks, i.e. lower exchange rate pass-through, should display lower price dispersion.

We also find that industries with greater expenditure share are positively correlated with higher pass-through elasticities. These results suggest that a significant share of households' expenditures go to categories displaying high pass-through rates. It also implies that the Mexican CPI might be particularly sensitive to exchange rate fluctuations.

When we continue our analysis by splitting the sample into goods (tradable) and services (non-tradables), we find some interesting highlights as well. Focus first in table 3.5 describing determinants of tradable goods' pass-through rates. What stands out in this table is that our proxy for demand conditions becomes positive and statistically significant correlation with tradable goods' pass-through. Thus, our results support those from Corsetti et al. [2005] and Choudhri and Hakura [2006] who argue that price-setters try change prices while positive economic conditions are in place. That is, findings suggest a traditional New Keynesian explanation: price-setters pass-through exchange rate costs at times of excess demand. Moreover, economic development also is indicative of greater pass-through of tradable goods. The idea proposed by Beck et al. [2009] and Kose et al. [2003] is that more developed regions are more integrated with commercial routes, hence more exposed to external factors. The rest of the determinants do not show great differences between tradable goods and the complete pool of industry-region estimates.

Pass-through determinants for services (non-tradables) are summarised in table 3.6. In contrast with the tradable goods basket, services have a negative relationship with output growth. This opposite direction in tradable and non-tradable items explains the statistically insignificant results form table 3.4. The reason why demand conditions affecting differently tradable and non-tradable items' pass-through might require an extensive and more detailed dataset. One potential explanation might come from the menu-cost literature- tradable goods might have lower costs to reset their prices, while non-tradable face higher costs when updating their price.

In other words, the more economic agents in the region, the lower pass-through is. The increase variety in goods and services as a result of a more saturated market, and therefore a lower pass-through rate, may be one potential explanation. Not surprisingly, determinants closely related to tradable goods are statistically insignificant when focusing only on services. Those are import intensity, inflation volatility and expenditure share.

Table 3.2: Regional pass-through

City	6-months	12-months	18-months	24-months
Acapulco, Gro.	0.058**	0.104*	0.091	0.080
Aguascalientes, Ags.	0.085***	0.132**	0.176**	0.189*
Campeche, Camp.	0.133***	0.190***	0.212***	0.192**
Cd. Acuna, Coah.	0.142***	0.192***	0.214**	0.198**
Cd. Jiminez, Chih.	0.097***	0.098*	0.062	0.042
Cd. Juarez, Chih.	0.146***	0.169**	0.181**	0.135
Chetumal, Q. R.	0.106***	0.132**	0.156**	0.114
Chihuahua, Chih.	0.068**	0.078	0.038	0.015
Colima, Col.	0.083***	0.137**	0.213***	0.174*
Cordoba, Ver.	0.090***	0.148**	0.177**	0.203**
Cortazar, Gto.	0.053**	0.073	0.098	0.067
Cuernavaca, Mor.	0.029	0.008	-0.019	-0.121
Culiacan, Sin.	0.064**	0.098*	0.099	0.063
Durango, Dgo.	0.035	0.056	0.062	0.043
Fresnillo, Zac.	0.101***	0.242***	0.292***	0.348***
Guadalajara, Jal.	0.063**	0.169**	0.232***	0.217**
Hermosillo, Son.	0.124***	0.136**	0.138*	0.062
Huatabampo, Son.	0.023	0.123*	0.128*	0.102
Iguala, Gro.	0.083***	0.094*	0.051	0.024
Jacona, Mich.	0.061**	0.033	0.010	-0.045
La Paz, B. C. S.	0.197***	0.287***	0.356***	0.278***
Leon, Gto.	0.019	0.091	0.120*	0.108
Matamoros, Tamps.	0.037	0.002	-0.022	-0.062
Merida, Yuc.	0.131***	0.179***	0.221**	0.234**
Mexicali, B. C.	0.146***	0.210***	0.252***	0.253**
Mexico City	0.066**	0.065	0.050	0.023
Monclova, Coah.	0.053*	0.071	0.078	0.048
Monterrey, N. L.	0.093***	0.167***	0.181**	0.170*
Morelia, Mich.	0.103***	0.161**	0.167**	0.133
Oaxaca, Oax.	0.045*	0.069	0.081	0.048
Puebla, Pue.	0.061**	0.083	0.049	-0.001
Queretaro, Qro.	0.076***	0.072	0.051	-0.035
San Andres Tuxtla, Ver.	0.017	0.023	0.013	-0.060
San Luis Potosi, S. L. P.	0.058**	0.157**	0.248***	0.281***
Tampico, Tamps.	0.056**	0.089*	0.140*	0.063
Tapachula, Chis.	0.115***	0.120**	0.153**	0.097
Tehuantepec, Oax.	0.079***	0.110*	0.133*	0.097
Tepatitlan, Jal.	0.051*	0.044	0.017	-0.041
Tepic, Nay.	0.098***	0.153**	0.184**	0.173*
Tijuana, B. C.	0.147***	0.134**	0.131	0.072
Tlaxcala, Tlax.	0.088***	0.152**	0.187**	0.203**
Toluca, Edo. de Mex.	0.062**	0.076	0.106	0.033
Torreon, Coah.	0.021	0.034	0.016	-0.009
Tulancingo, Hgo.	0.108***	0.145**	0.146*	0.106
Veracruz, Ver.	0.061**	0.105*	0.153**	0.119
Villahermosa, Tab.	0.123***	0.164***	0.219***	0.213**

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.01$

All estimates are statistically different from 1 at 1%

Table 3.3: Industry pass-through

NAICS	Industry	6-months	12-months	18-months	24-months
3111	Animal food manuf	-0.065	0.078	0.124	0.121
3112	Grain, fats and oils manuf	-0.059	-0.125	-0.134	-0.184
3114	Stews and prepared meals	0.055**	0.090*	0.038	0.006
3115	Dairy prods manuf	0.056***	-0.001	0.108**	0.174**
3116	Livestock, poultry and other	0.230***	0.231***	0.248***	0.196**
3117	Seafood prep and packaging	0.267***	0.590***	0.690***	0.668***
3118	Bakery prodsand tortilla manuf	0.093***	0.159***	0.064	-0.087
3119	Other food manuf	0.138***	0.228***	0.258***	0.230***
3121	Beverage industry	0.062***	0.107**	0.154**	0.152**
3122	Tobacco industry	0.132***	0.270***	0.375***	0.360**
3141	Cut and sew rugs manuf	0.056*	0.087	0.074	0.052
3149	Other textile prods manuf	0.018	-0.048	-0.040	-0.053
3151	Knitted apparel manuf	0.074**	0.190***	0.239***	0.197**
3152	Cut and sew apparel manuf	0.029*	0.073*	0.083*	0.084
3162	Footwear manuf	0.055**	0.101*	0.126*	0.121*
3169	Leather, hide and allied manuf	-0.015	-0.060	-0.083	-0.098
3222	Paperboard and paper manuf	-0.061	-0.135	-0.128	-0.107
3241	Petroleum and coal prods manuf	0.158***	0.146	0.034	-0.116
3253	Fertilizers, pesticides and others	0.074	0.135	0.300	0.322
3254	Pharmaceutical prods manuf	0.121***	0.225***	0.237***	0.270***
3256	Soaps and cleaners manuf	0.159***	0.197***	0.214***	0.221***
3259	Other chemical prods manuf	0.204***	0.363**	0.469***	0.528***
3261	Plastic prods manuf	0.037	-0.062	-0.109	-0.224
3272	Glass and glass prods manuf	0.044	-0.015	-0.028	-0.132
3322	Kitchen utensils manuf	0.087*	-0.089	-0.050	-0.075
3333	Commercial machinery and equip	0.035	0.159	0.250	0.238
3334	Air conditioning and heating equip	0.122**	0.181	0.221	0.247
3341	Computer and peripheral equip	0.092**	0.187**	0.231**	0.220*
3343	Audio and video equip manuf	0.102***	0.172**	0.229***	0.251**
3346	Manuf magnetic and optical media	0.069*	0.112	0.112	0.027
3351	Lighting accessories manuf	0.337***	0.767***	0.969***	0.919**
3352	Household electrical appliances	0.189***	0.260***	0.251***	0.187**
3359	Other electrical equip manuf	0.038	0.102	0.221*	0.336**
3361	Automobiles and trucks manuf	0.088***	0.273***	0.433***	0.500***
3363	Motor vehicle parts manuf	0.084*	0.037	0.038	-0.030
3369	Other transportation equip manuf	0.195***	0.395***	0.569***	0.601***
3371	Furniture, except office furniture	0.099**	0.203**	0.175*	0.154
3391	Medical, dental and lab equip	0.051	0.021	0.032	0.085
3399	Other manuf industries	0.061**	0.076	0.070	0.040
4852	Long-distance passenger transp	-0.044	0.070	0.110	0.054
5111	Newspapers, books, and others	0.053***	0.069*	0.090**	0.091*
5171	Wired telecommunications carriers	-0.036	-0.078	-0.102	-0.163
5313	Serv related to real estate	-0.045	-0.086	-0.132	-0.168
5412	Accounting and auditing serv	0.118*	0.077	0.025	-0.177
6211	Medical doctors offices	0.023	0.034	0.063	0.058
6212	Dental offices	0.052*	0.110	0.116	0.092
6215	Medical and diagnostic laboratories	-0.057	-0.012	-0.115	-0.155
6221	General hospitals	0.071***	0.153***	0.205***	0.200***
7139	Other recreational serv	0.010	0.049	0.035	0.007
7221	Restaurants full service	-0.010	-0.003	-0.016	-0.039
7222	Restaurants and take aways	0.122***	0.120	0.106	0.135
7224	Nightclubs and bars	0.058**	0.114*	0.113	0.099
8111	Maintenance of automobiles	0.081**	0.151*	0.227**	0.266**
8114	Household goods maintenance	-0.072	-0.151	-0.176	-0.191
8121	Beauty salons and public baths	-0.021	-0.019	-0.008	-0.028
8122	Laundries and dry-cleaning shops	0.009	-0.024	0.002	-0.023
8123	Funeral serv	0.055	0.123	0.168*	0.158
8141	Domestic personnel	0.023	0.059	0.105*	0.130*

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.01$

Indistries 3117, 3351 and 3369 fail to reject pass-through is statistically different from 1 at 1%

Figure 3.5: Regional ERPT at different time horizons

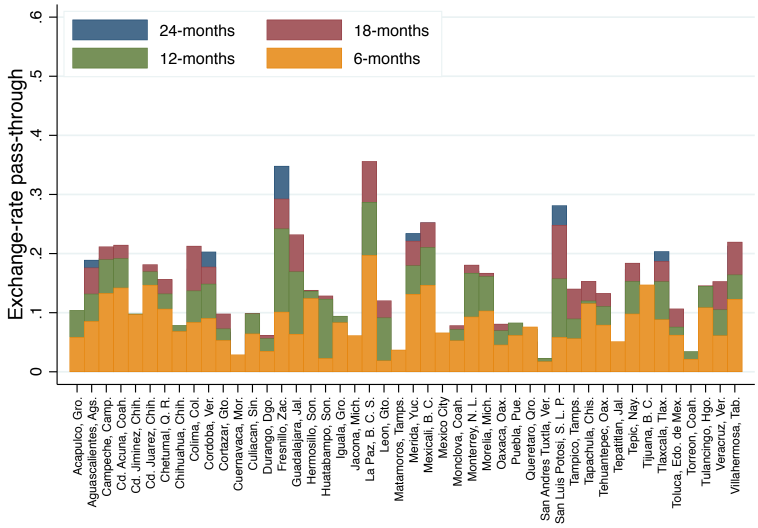


Figure 3.6: Industry ERPT at different time horizons

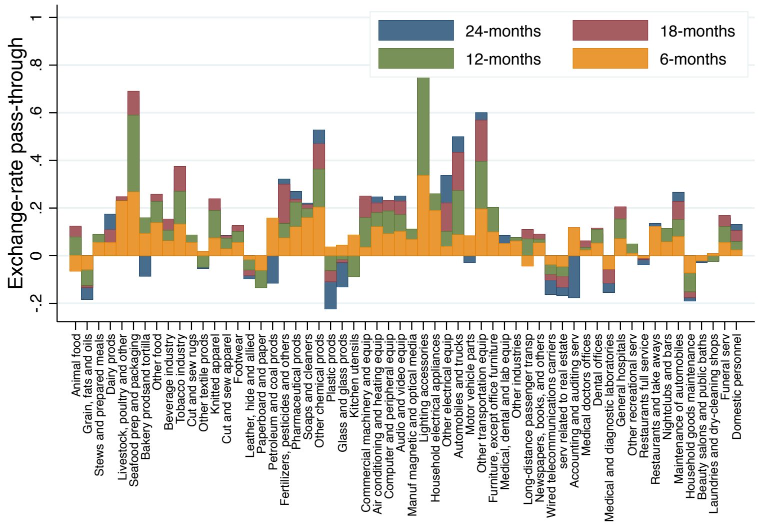


Table 3.4: ERPT Determinants

VARIABLES	(1) All 6-months	(2) All 12-months	(3) All 18-months	(4) All 24-months
Distance to US	0.030**	0.044**	0.072**	0.057
	(0.012)	(0.020)	(0.030)	(0.040)
Market Density	-0.375***	-0.655***	-1.054***	-1.122**
	(0.123)	(0.219)	(0.345)	(0.424)
Output Growth	0.023	0.058	0.078	0.108
	(0.022)	(0.041)	(0.060)	(0.084)
Economic Development	-0.000	0.040	0.016	0.045
	(0.020)	(0.032)	(0.048)	(0.067)
Import Intensity	0.079***	0.188***	0.252***	0.281***
	(0.013)	(0.021)	(0.029)	(0.036)
Local Volatility	0.878***	0.250	0.091	-0.222
	(0.172)	(0.307)	(0.489)	(0.626)
Expenditure Share	0.599***	0.892***	1.105***	1.017***
	(0.119)	(0.205)	(0.269)	(0.342)
Constant	-0.219***	-0.301**	-0.482**	-0.395
	(0.080)	(0.145)	(0.218)	(0.289)
Observations	2,668	2,668	2,668	2,668
R-squared	0.056	0.059	0.055	0.041

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.5: ERPT Determinants for tradables

VARIABLES	(1) All 6-months	(2) All 12-months	(3) All 18-months	(4) All 24-months	(5) Tradables 6-months	(6) Tradables 12-months	(7) Tradables 18-months	(8) Tradables 24-months
Distance to US	0.030**	0.044**	0.072**	0.057	0.002	0.015	0.033	0.012
	(0.012)	(0.020)	(0.030)	(0.040)	(0.019)	(0.030)	(0.044)	(0.056)
Market Density	-0.375***	-0.655***	-1.054***	-1.122**	-0.213	-0.547*	-0.822*	-0.836
	(0.123)	(0.219)	(0.345)	(0.424)	(0.162)	(0.276)	(0.416)	(0.503)
Output Growth	0.023	0.058	0.078	0.108	0.063*	0.158***	0.226**	0.288**
	(0.022)	(0.041)	(0.060)	(0.084)	(0.033)	(0.059)	(0.087)	(0.110)
Economic Development	-0.000	0.040	0.016	0.045	0.058**	0.126***	0.139**	0.188**
	(0.020)	(0.032)	(0.048)	(0.067)	(0.025)	(0.044)	(0.067)	(0.091)
Import Intensity	0.079***	0.188***	0.252***	0.281***	0.030**	0.114***	0.173***	0.223***
	(0.013)	(0.021)	(0.029)	(0.036)	(0.014)	(0.024)	(0.031)	(0.040)
Local Volatility	0.878***	0.250	0.091	-0.222	0.380**	-0.730**	-0.864	-0.889
	(0.172)	(0.307)	(0.489)	(0.626)	(0.187)	(0.332)	(0.556)	(0.700)
Expenditure Share	0.599***	0.892***	1.105***	1.017***	0.631***	0.929***	1.276***	1.328***
	(0.119)	(0.205)	(0.269)	(0.342)	(0.173)	(0.283)	(0.345)	(0.450)
Constant	-0.219***	-0.301**	-0.482**	-0.395	0.006	-0.050	-0.186	-0.100
	(0.080)	(0.145)	(0.218)	(0.289)	(0.133)	(0.214)	(0.324)	(0.409)
Observations	2,668	2,668	2,668	2,668	1,794	1,794	1,794	1,794
R-squared	0.056	0.059	0.055	0.041	0.014	0.032	0.034	0.031

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.6: ERPT Determinants for services

VARIABLES	(1) All 6-months	(2) All 12-months	(3) All 18-months	(4) All 24-months	(5) Services 6-months	(6) Services 12-months	(7) Services 18-months	(8) Services 24-months
Distance to US	0.030**	0.044**	0.072**	0.057	0.079***	0.092***	0.139***	0.138***
	(0.012)	(0.020)	(0.030)	(0.040)	(0.019)	(0.028)	(0.034)	(0.048)
Market Density	-0.375***	-0.655***	-1.054***	-1.122**	-0.718***	-0.933***	-1.551***	-1.696***
	(0.123)	(0.219)	(0.345)	(0.424)	(0.213)	(0.300)	(0.481)	(0.566)
Output Growth	0.023	0.058	0.078	0.108	-0.040	-0.103*	-0.161**	-0.185*
	(0.022)	(0.041)	(0.060)	(0.084)	(0.032)	(0.054)	(0.080)	(0.107)
Economic Development	-0.000	0.040	0.016	0.045	-0.092**	-0.089	-0.175*	-0.183
	(0.020)	(0.032)	(0.048)	(0.067)	(0.038)	(0.069)	(0.091)	(0.123)
Import Intensity	0.079***	0.188***	0.252***	0.281***	-0.000	-0.014	0.001	-0.034
	(0.013)	(0.021)	(0.029)	(0.036)	(0.040)	(0.063)	(0.087)	(0.113)
Local Volatility	0.878***	0.250	0.091	-0.222	0.617	0.344	-0.273	-1.118
	(0.172)	(0.307)	(0.489)	(0.626)	(0.521)	(0.801)	(1.322)	(1.868)
Expenditure Share	0.599***	0.892***	1.105***	1.017***	-0.039	-0.144	-0.176	-0.383
	(0.119)	(0.205)	(0.269)	(0.342)	(0.173)	(0.298)	(0.387)	(0.476)
Constant	-0.219***	-0.301**	-0.482**	-0.395	-0.497***	-0.532***	-0.775***	-0.724**
	(0.080)	(0.145)	(0.218)	(0.289)	(0.123)	(0.186)	(0.234)	(0.324)
Observations	2,668	2,668	2,668	2,668	874	874	874	874
R-squared	0.056	0.059	0.055	0.041	0.031	0.019	0.023	0.018

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

3.7 Conclusions

In nowadays globally integrated economies, policy makers are concerned on how external factors affect domestic economic activity. This research focuses on the so-called Exchange Rate Pass-Through, which is the elasticity of price response with respect to exchange rate fluctuations.

In this chapter, we analyse whether pass-through is heterogeneous across different regions and industries in Mexico. A novel contribution of this research is that, using a large micro-dataset with thousands of price dynamics from a wide range of goods and services from various locations, we document that pass-through is asymmetric in Mexico. For instance, after 6 months, some regions exhibit up to 4 times larger pass-through rates than other urban zones. This effect is persistent even at longer horizons. Also, we find some evidence that pass-through pace is heterogeneous as well. That is, in some regions exchange rate effects take less than a year, whereas some other regions take longer. In addition, we confirm previous findings arguing that pass-through is heterogeneous across industries. On average, tradable goods display higher pass-through elasticities than services for instance.

The second contribution of this research is to associate likely local and industry characteristics driving the pass-through responses. We study factors such as distance to the north border, market density, demand conditions, economic development, import intensity, price change dispersion and expenditure share. We find that affecting positively pass-through elasticities are distance to the border, import intensity, price change dispersion and expenditure share. In contrast, market density has a negative relationship with pass-through rates. Moreover, we find that demand conditions and economic development are positively associated with tradable goods' pass-through responses.

These results have a number of implications in the study of ERPT as a macro phenomenon. First, the use of micro-data continues to suggest that ERPT is alive and well, contrary to what macro studies in recent years argue. Reconciling evidence found from rich micro-data analysis and traditional aggregate data continues as a prosperous area of research. Second, despite the homogeneous tax and regulation system across Mexican states, regional price responses are asymmetric to an economy wide cost shock, namely exchange rate fluctuations. This result urges further research on micro features shaping pass-through elasticities. Third, although only a few, price of services are also affected by exchange rate fluctuations. This result is at odds with the standard assumption that non-tradable goods or services exhibit zero pass-through rates. Research on non-tradable goods is important for both theory and policy implications of exchange rate pass-through.

3.8 Appendix

Figure 3.7: Appendix: MXN Peso Effective Exchange Rate (EER)

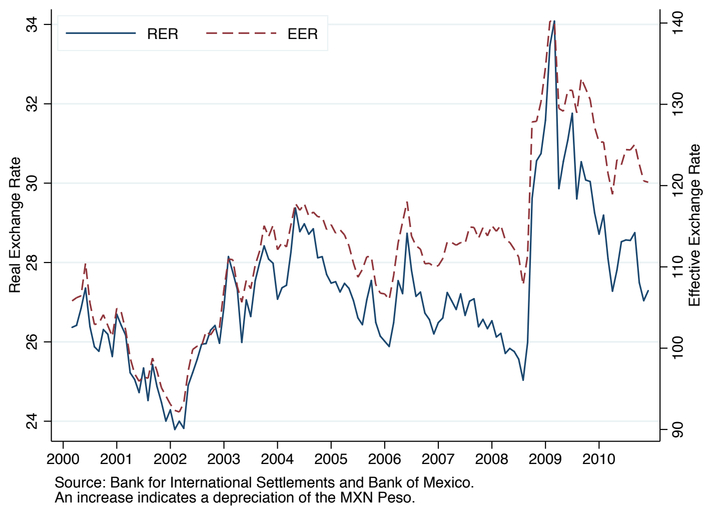


Figure 3.8: Appendix: Regional ERPT after 6 months

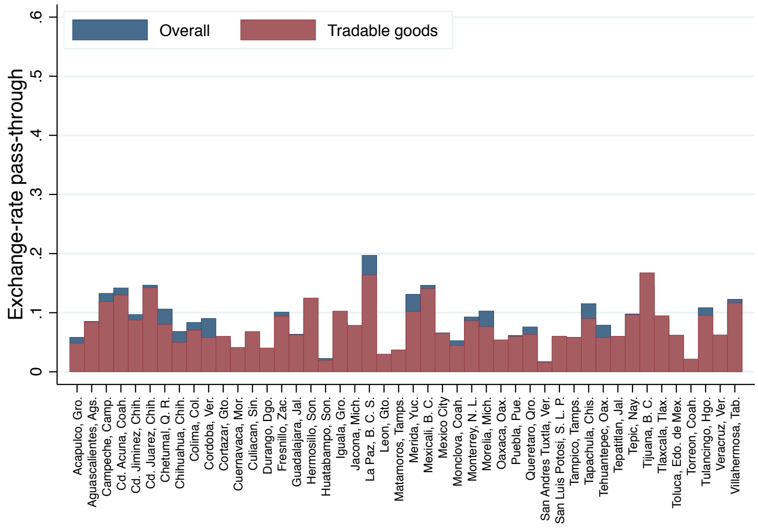


Figure 3.9: Appendix: Regional ERPT after 12 months

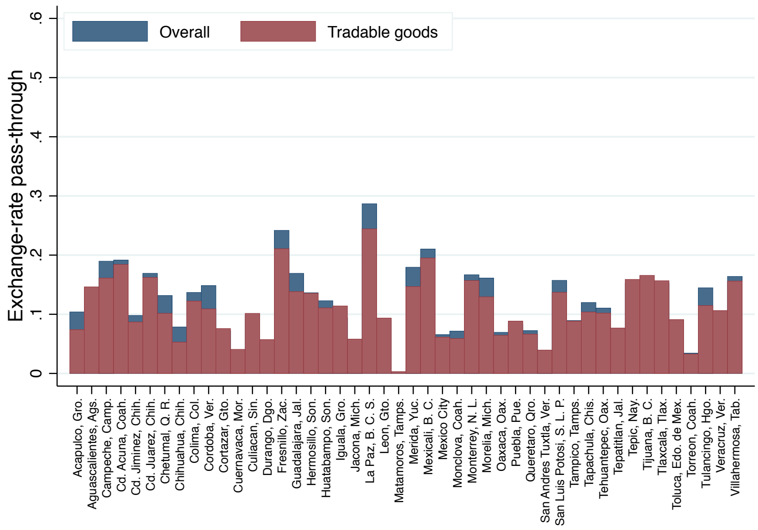


Figure 3.10: Appendix: Regional ERPT after 18 months

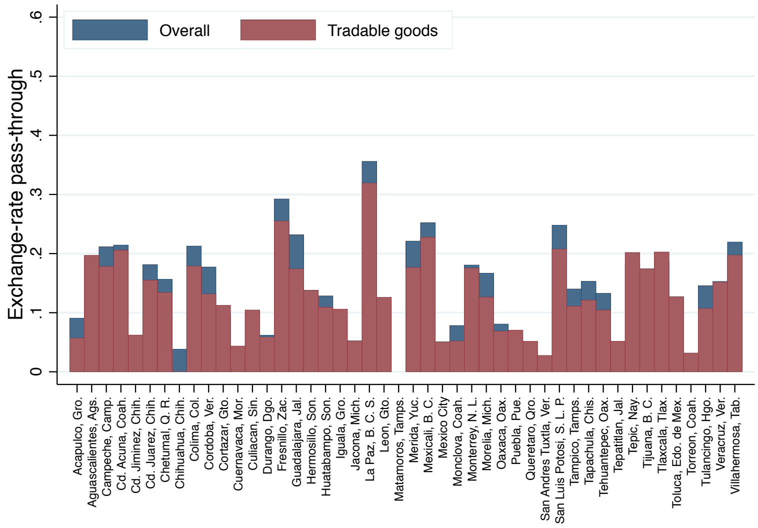


Figure 3.11: Appendix: Regional ERPT after 24 months

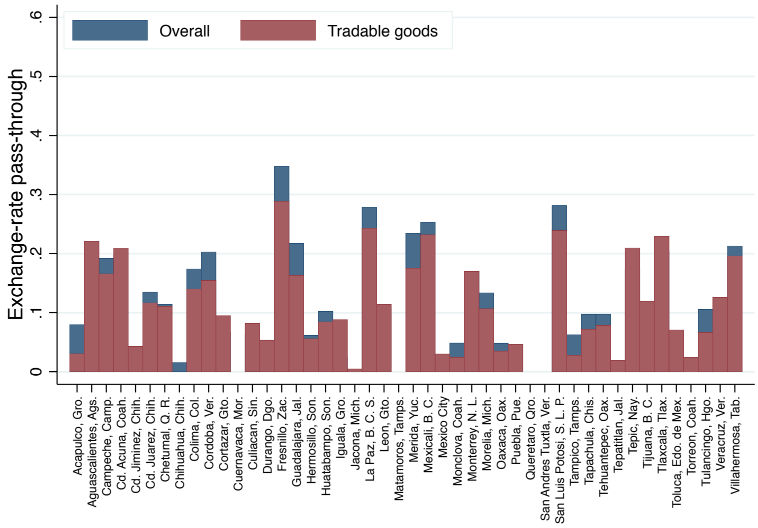


Table 3.7: Appendix: ERPT Determinants, after 6 months

VARIABLES	(1) All 6-months	(2) All 6-months	(3) All 6-months	(4) All 6-months	(5) All 6-months	(6) All 6-months	(7) All 6-months	(8) All 6-months
Distance to US	0.030**	0.014						
	(0.012)	(0.014)						
Market Density	-0.375***		-0.264**					
	(0.123)		(0.110)					
Output Growth	0.023			0.030				
	(0.022)			(0.027)				
Economic Development	-0.000				0.033			
	(0.020)				(0.022)			
Import Intensity	0.079***					0.090***		
	(0.013)					(0.013)		
Local Volatility	0.878***						1.142***	
	(0.172)						(0.184)	
Expenditure Share	0.599***							0.417***
	(0.119)							(0.106)
Constant	-0.219***	-0.045	0.081***	0.047***	0.050***	0.022***	0.007	0.051***
	(0.080)	(0.103)	(0.011)	(0.010)	(0.007)	(0.006)	(0.008)	(0.004)
Observations	2,668	2,668	2,668	2,668	2,668	2,668	2,668	2,668
R-squared	0.056	0.001	0.003	0.001	0.001	0.029	0.025	0.003

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.8: Appendix: ERPT Determinants, after 12 months

VARIABLES	(1) All 12-months	(2) All 12-months	(3) All 12-months	(4) All 12-months	(5) All 12-months	(6) All 12-months	(7) All 12-months	(8) All 12-months
Distance to US	0.044**	0.025						
	(0.020)	(0.023)						
Market Density	-0.655***		-0.439**					
	(0.219)		(0.186)					
Output Growth	0.058			0.055				
	(0.041)			(0.053)				
Economic Development	0.040				0.085**			
	(0.032)				(0.036)			
Import Intensity	0.188***					0.185***		
	(0.021)					(0.020)		
Local Volatility	0.250						0.904***	
	(0.307)						(0.324)	
Expenditure Share	0.892***							0.537**
	(0.205)							(0.200)
Constant	-0.301**	-0.093	0.134***	0.074***	0.076***	0.022**	0.054***	0.086***
	(0.145)	(0.169)	(0.018)	(0.020)	(0.011)	(0.009)	(0.013)	(0.008)
Observations	2,668	2,668	2,668	2,668	2,668	2,668	2,668	2,668
R-squared	0.059	0.001	0.003	0.001	0.002	0.045	0.006	0.002

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.9: Appendix: ERPT Determinants, after 18 months

VARIABLES	(1) All 18-months	(2) All 18-months	(3) All 18-months	(4) All 18-months	(5) All 18-months	(6) All 18-months	(7) All 18-months	(8) All 18-months
Distance to US	0.072**	0.035						
	(0.030)	(0.035)						
Market Density	-1.054***		-0.663**					
	(0.345)		(0.303)					
Output Growth	0.078			0.080				
	(0.060)			(0.079)				
Economic Development	0.016				0.091*			
	(0.048)				(0.049)			
Import Intensity	0.252***					0.243***		
	(0.029)					(0.028)		
Local Volatility	0.091						1.021*	
	(0.489)						(0.521)	
Expenditure Share	1.105***							0.603**
	(0.269)							(0.288)
Constant	-0.482**	-0.150	0.174***	0.085***	0.095***	0.020	0.069***	0.105***
	(0.218)	(0.257)	(0.030)	(0.029)	(0.014)	(0.014)	(0.020)	(0.011)
Observations	2,668	2,668	2,668	2,668	2,668	2,668	2,668	2,668
R-squared	0.055	0.001	0.004	0.001	0.001	0.041	0.004	0.001

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.10: Appendix: ERPT Determinants, after 24 months

VARIABLES	(1) All 24-months	(2) All 24-months	(3) All 24-months	(4) All 24-months	(5) All 24-months	(6) All 24-months	(7) All 24-months	(8) All 24-months
Distance to US	0.057	0.026						
	(0.040)	(0.043)						
Market Density	-1.122**		-0.767**					
	(0.424)		(0.372)					
Output Growth	0.108			0.090				
	(0.084)			(0.098)				
Economic Development	0.045				0.108*			
	(0.067)				(0.064)			
Import Intensity	0.281***					0.266***		
	(0.036)					(0.035)		
Local Volatility	-0.222						0.880	
	(0.626)						(0.657)	
Expenditure Share	1.017***							0.413
	(0.342)							(0.370)
Constant	-0.395	-0.100	0.164***	0.063*	0.072***	-0.007	0.056**	0.089***
	(0.289)	(0.318)	(0.036)	(0.037)	(0.019)	(0.017)	(0.025)	(0.014)
Observations	2,668	2,668	2,668	2,668	2,668	2,668	2,668	2,668
R-squared	0.041	0.000	0.003	0.001	0.001	0.031	0.002	0.000

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.11: Appendix: ERPT Determinants for tradable goods, after 6 months

VARIABLES	(1) All 6-months	(2) Goods 6-months	(3) Goods 6-months	(4) Goods 6-months	(5) Goods 6-months	(6) Goods 6-months	(7) Goods 6-months	(8) Goods 6-months	(9) Goods 6-months
Distance to US	0.030**	0.002	0.007						
	(0.012)	(0.019)	(0.018)						
Market Density	-0.375***	-0.213		-0.206					
	(0.123)	(0.162)		(0.157)					
Output Growth	0.023	0.063*			0.046				
	(0.022)	(0.033)			(0.031)				
Economic Development	-0.000	0.058**				0.059**			
	(0.020)	(0.025)				(0.023)			
Import Intensity	0.079***	0.030**					0.011		
	(0.013)	(0.014)					(0.012)		
Local Volatility	0.878***	0.380**						0.291	
	(0.172)	(0.187)						(0.200)	
Expenditure Share	0.599***	0.631***							0.484***
	(0.119)	(0.173)							(0.154)
Constant	-0.219***	0.006	0.033	0.103***	0.068***	0.072***	0.078***	0.069***	0.077***
	(0.080)	(0.133)	(0.136)	(0.016)	(0.011)	(0.008)	(0.007)	(0.012)	(0.005)
Observations	2,668	1,794	1,794	1,794	1,794	1,794	1,794	1,794	1,794
R-squared	0.056	0.014	0.000	0.002	0.002	0.002	0.000	0.001	0.004

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.12: Appendix: ERPT Determinants for tradable goods, after 12 months

VARIABLES	(1) All 12-months	(2) Goods 12-months	(3) Goods 12-months	(4) Goods 12-months	(5) Goods 12-months	(6) Goods 12-months	(7) Goods 12-months	(8) Goods 12-months	(9) Goods 12-months
Distance to US	0.044**	0.015	0.031						
	(0.020)	(0.030)	(0.029)						
Market Density	-0.655***	-0.547*		-0.353					
	(0.219)	(0.276)		(0.239)					
Output Growth	0.058	0.158***			0.124**				
	(0.041)	(0.059)			(0.060)				
Economic Development	0.040	0.126***				0.122**			
	(0.032)	(0.044)				(0.047)			
Import Intensity	0.188***	0.114***					0.109***		
	(0.021)	(0.024)					(0.022)		
Local Volatility	0.250	-0.730**						-0.992**	
	(0.307)	(0.332)						(0.393)	
Expenditure Share	0.892***	0.929***							0.620**
	(0.205)	(0.283)							(0.259)
Constant	-0.301**	-0.050	-0.091	0.169***	0.093***	0.112***	0.078***	0.190***	0.128***
	(0.145)	(0.214)	(0.218)	(0.024)	(0.023)	(0.013)	(0.012)	(0.020)	(0.010)
Observations	2,668	1,794	1,794	1,794	1,794	1,794	1,794	1,794	1,794
R-squared	0.059	0.032	0.001	0.002	0.005	0.003	0.011	0.006	0.002

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.13: Appendix: ERPT Determinants for tradable goods, after 18 months

VARIABLES	(1) All 18-months	(2) Goods 18-months	(3) Goods 18-months	(4) Goods 18-months	(5) Goods 18-months	(6) Goods 18-months	(7) Goods 18-months	(8) Goods 18-months	(9) Goods 18-months
Distance to US	0.072**	0.033	0.049						
	(0.030)	(0.044)	(0.045)						
Market Density	-1.054***	-0.822*		-0.475					
	(0.345)	(0.416)		(0.334)					
Output Growth	0.078	0.226**			0.190**				
	(0.060)	(0.087)			(0.093)				
Economic Development	0.016	0.139**				0.143**			
	(0.048)	(0.067)				(0.069)			
Import Intensity	0.252***	0.173***					0.163***		
	(0.029)	(0.031)					(0.029)		
Local Volatility	0.091	-0.864						-1.240*	
	(0.489)	(0.556)						(0.650)	
Expenditure Share	1.105***	1.276***							0.766*
	(0.269)	(0.345)							(0.391)
Constant	-0.482**	-0.186	-0.198	0.211***	0.100***	0.138***	0.081***	0.234***	0.156***
	(0.218)	(0.324)	(0.332)	(0.035)	(0.032)	(0.018)	(0.017)	(0.031)	(0.016)
Observations	2,668	1,794	1,794	1,794	1,794	1,794	1,794	1,794	1,794
R-squared	0.055	0.034	0.002	0.002	0.006	0.003	0.013	0.005	0.002

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3.14: Appendix: ERPT Determinants for tradable goods, after 24 months

VARIABLES	(1) All 24-months	(2) Goods 24-months	(3) Goods 24-months	(4) Goods 24-months	(5) Goods 24-months	(6) Goods 24-months	(7) Goods 24-months	(8) Goods 24-months	(9) Goods 24-months
Distance to US	0.057	0.012	0.043						
	(0.040)	(0.056)	(0.054)						
Market Density	-1.122**	-0.836		-0.547					
	(0.424)	(0.503)		(0.419)					
Output Growth	0.108	0.288**			0.227*				
	(0.084)	(0.110)			(0.114)				
Economic Development	0.045	0.188**				0.169*			
	(0.067)	(0.091)				(0.090)			
Import Intensity	0.281***	0.223***					0.210***		
	(0.036)	(0.040)					(0.037)		
Local Volatility	-0.222	-0.889						-1.295	
	(0.626)	(0.700)						(0.790)	
Expenditure Share	1.017***	1.328***							0.602
	(0.342)	(0.450)							(0.525)
Constant	-0.395	-0.100	-0.172	0.199***	0.068	0.114***	0.038*	0.219***	0.141***
	(0.289)	(0.409)	(0.404)	(0.043)	(0.041)	(0.024)	(0.021)	(0.038)	(0.020)
Observations	2,668	1,794	1,794	1,794	1,794	1,794	1,794	1,794	1,794
R-squared	0.041	0.031	0.001	0.002	0.006	0.002	0.014	0.003	0.001

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Chapter 4

Conclusions

This dissertation adds to the research of using large micro datasets to document heterogeneity in price and wage setting, its implications for aggregate dynamics and potential drivers shaping heterogeneous responses.

In chapter 1, "Price and Wage-setting Heterogeneity and Implications in a New Keynesian Economy", two large price and wage micro-datasets are merged at the industry level. To the author's knowledge, this is the first study merging price and wage data in such a large scale. Studying jointly prices and wages new stylised facts emerge from the data: (i) the frequency of price adjustment is positively correlated with the frequency of wage updates across industries; (ii) wage stickiness is greater than the stickiness of reference prices but lower than posted price rigidities; (iii) frequency of adjustments is heterogeneous across industries for both prices and wages; (iv) absolute size of price adjustments is heterogeneous for prices but less clear for wages; and (v) frequency and size of adjustments are negatively correlated, not only for prices but for wages as well.

Results suggest that heterogeneous nominal rigidities have major implications for aggregate dynamics. Using a multi-sector DSGE model with time-dependent price and wage setting workhorse framework, simulations indicate that adding heterogeneity in both prices and wages has small differences in aggregate dynamics compared to a model with heterogeneity in one end while keeping the other homogeneous. Hence, further complicating the model to encompass both sources of heterogeneity has little payoff in terms of real effects and persistency. Though, any heterogeneous economy generates far more real effects than any homogeneous economy. Therefore, NK models that abstract from price or wage heterogeneity neglect an important channel of monetary policy effects.

As a bypass, and since adding heterogeneous nominal rigidities obscures an already complicated model, we revisit the question of what calibration a homogeneous economy should follow in order to generate the same real effects as a heterogeneous economy. Our analysis suggests that a homogeneous economy calibrated with 3/4 of the weighted mean of frequency of price and wage adjustments generates the same real effects as the heterogeneous economy.

In chapter 2, "Heterogeneous Exchange Rate Pass-Through: Micro-Level Evidence From Mexico", the attention is centred in the price microdata and it examines whether price responses are heterogeneous to exchange rate shocks and, if so, what factors are likely to determine these responses.

Estimates show that (i) pass-through is incomplete at most horizons, industries and regions; (ii) there is a great deal of heterogeneity in pass-through elasticities; (iii) pass-through pace is also heterogeneous; and (iv) pass-through is heterogeneous across industries is confirmed.

In contrast to most pass-through studies calculating price elasticities to exchange rates only, this research takes a step further and assesses local and industry characteristics in driving the pass-through responses. The evidence indicates that affecting positively pass-through elasticities are distance to the border, import intensity, price change dispersion and expenditure share. In contrast, market density has a negative relationship with pass-through rates. Moreover, we find that demand conditions and economic development are positively associated with tradable goods' pass-through responses.

In conclusion, the main takeaways of this PhD dissertation are threefold. First, results of Chapters 1 and 2 suggest that we are far from fully understanding the key determinants generating heterogeneous nominal rigidities. Heterogeneity is present for different types of products or firms, types of contacts, and types of industry structure. Without comprehending these drivers, characterisation of reality may lack from important features. For instance, industries changing more frequently wages are likely to be those updating prices more often.

Second, there is no reason to keep building on "representative" firms models. Aggregate dynamics are noticeably affected by the presence of heterogeneous price- and wage-setters. In fact, embracing heterogeneity would greatly benefit macro modelling since (i) it is consistent with microdata and (ii) avoids using ad-hoc solutions generating greater output persistence (such as indexation and/or habit formation).

Third, pass-through is alive and well. Despite finding far from complete pass-through elasticities, there is significant evidence that pass-through is significant and, importantly, heterogeneous within an economy. This evidence based on microdata contradicts recent studies using aggregate data.

More broadly, future areas of research should work to develop a tractable and understandable ways to incorporate the varieties of wage and price setting practices. This would greatly assist policy analysis. Moreover, as we move on into a "big data", economic research is desperate for a reliable time-series panel-data toolbox. This research could help reconciling the common gap between studies using micro and aggregate data.

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